White Paper

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Project Director: Jill Sterrett

Institution: San Francisco Museum of Modern Art

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Realizing a Sustainable San Francisco Museum of Modern Art

Photograph of artwork moving into the Cold Storage Vault is by Richard Barnes for California Sunday's article "Quality Control: Storing and restoring the new SFMOMA." Pictured here is Thomas Struth's Galleria dell'Accademia 1, Venice*.*

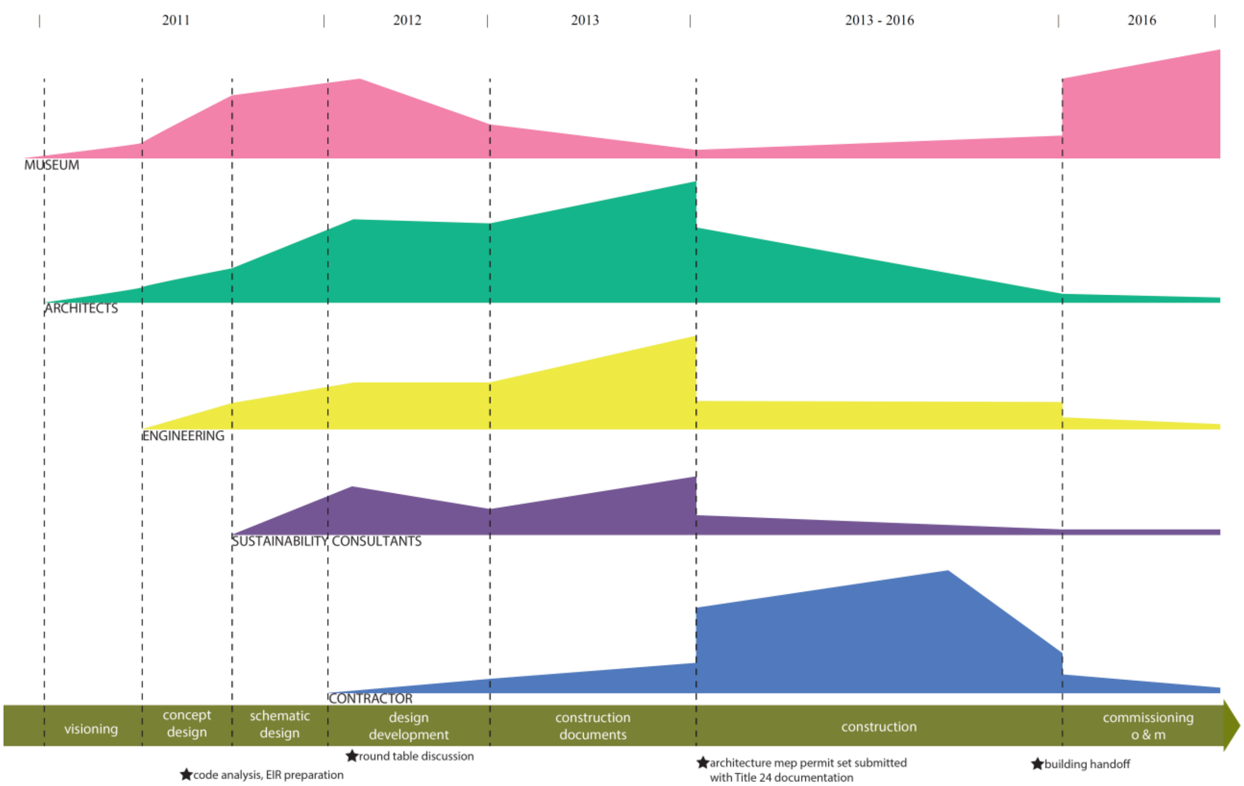
Project Summary

Funding from the National Endowment for the Humanities' Sustaining Cultural Heritage Collections Implementation Grant supported the San Francisco Museum of Modern Art's (SFMOMA) efforts to enhance the preservation and use of the museum's distinguished photography collection from October 1, 2013 through June 30, 2016. The project included the purchase and installation of art storage furniture for two new storage vaults, the Cold Storage Vault and the Study Center Storage Vault, that house the majority of SFMOMA's photography collection within the museum's expanded building and allows for the projected growth of the collection through 2027. The storage systems purchased for these new vaults have been integral to a larger museum building expansion project that complies with the City of San Francisco's Green Building Ordinance, one of the nation's most rigorous building codes for the reduction of waste in the built environment.

This white paper discusses the collaborative processes of sustainable design, construction and commissioning and provides the specifications for key lighting and HVAC conditions at SFMOMA.

Introduction

The processes of museum design, construction and commissioning involved a range of experts working in coordination for many years, including museum experts, architects, engineers, sustainability consultants and contractors. A description of the project team workflow is as follows. This white paper organizes the activities central to achieving LEED Gold Standard and meeting San Francisco's Green Building Ordinance by these standard phases of design and implementation.



SFMOMA design process and workflow diagram produced by Snøhetta

Visioning and Concept Design

Situated in the Bay Area, a center of environmentally conscious thought and progressive energy regulations, the design of the new SFMOMA embodies the dedication of a diverse project team—including museum curators, conservators and registrars, architects, engineers, sustainability consultants, contractors, and project managers—to sustainability and green initiatives. This project team was instrumental in incorporating many sustainable features into the new SFMOMA.

Achieving the LEED Gold standard and meeting California's Green Building Ordinance criteria for the expansion required an inventive approach to lighting and environmental controls. The curatorial team stressed the need for refined architectural details in the galleries, as well as ensuring that the technological and mechanical requirements to maintain gallery conditions remain nearly invisible so as to not dominate or affect the viewer's experience of the art.

The rigorous building standards required by the San Francisco's Green Building Ordinance led curators, conservators, and registrars at SFMOMA to analyze the nature and use of its collection, the building envelope, the museum's environmental criteria and the local climate, as well as energy use and environmental impact. The group identified the need for a cohesive plan that balances preservation effectiveness, cost and environmental impact. Almost immediately, it was apparent that contemplating cold storage as part of the overall photography storage systems would detract from the energy efficiency mandated by the Green Building Ordinance. This meant that SFMOMA's systems for photography storage, if allowed to include cold storage, had to be viewed within a larger plan for energy efficiency.

Schematic Design, Design Development and Construction

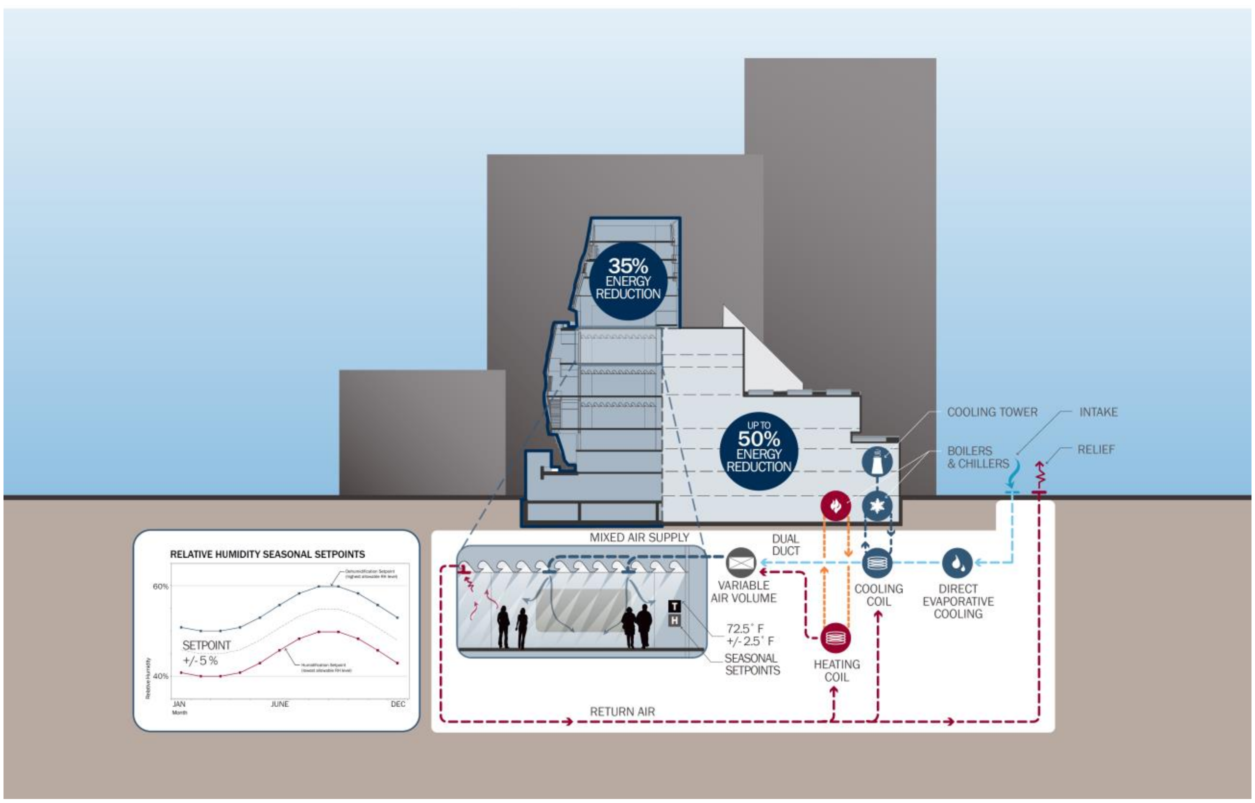
SFMOMA's architecture firm Snøhetta managed the design process and worked with leading sustainability consultants Atelier Ten, with local architecture firm EHDD in charge of the LEED coordination. This project team with engineering firm Taylor Engineering and commercial lighting design consultants Arup lighting ensured that the design was effectively and creatively meeting both the code requirements and goals of the museum. This project team identified two critical areas of collaborative exploration and study: environmental conditioning guidelines for the museum and LED (light-emitting diodes) lighting options for the galleries study rooms and storage vaults.

SFMOMA convened a roundtable summit in 2012, with national and international leaders on the topic of museum environments. The objective was to reach consensus on climate criteria, where stability of the interior art environment is preserved while permitting an energy-efficient response to seasonal fluctuations in the local climate. The resulting environmental guideline proposed museum temperature set points be consistent throughout the year (72.5 ± 2.5%) while allowing for seasonal adjustments in relative humidity (RH) to track according to monthly seasonal changes (55% ± 5% RH in San Francisco's cool summer months and 45% ± 5% RH in the mild winter months). This approach was instrumental in the realization of the project's energy goals. This proposal, consistent with ASHRAE Class A category, was approved by the American Institute for Conservation (AIC) in 2012 as an acceptable solution within the Class A category and subsequently ratified by the Association of Art Museum Directors in 2013 (see Appendix A).

SFMOMA worked with the expansion building architects Snøhetta and lighting consultants Arup to construct a complete gallery mock-up, including floors, walls, and ceiling details to test short-listed LED lighting options at the museum's Collections Center. In the spring of 2013, select works from the SFMOMA collection were installed within this mock-up gallery for viewing to build broad interdepartmental consensus around the LED lighting option that provides the optimal balance between aesthetic qualities of viewing, long-term preservation of artworks, and overall energy efficiency (See Appendix B).

SFMOMA staff and consultants viewing LED lighting in the museum's mock-up gallery

In July 2014, Atelier Ten (with input from Snøhetta, Taylor Engineering, and Arup) submitted an update to SFMOMA based on the Construction Documents and reported that SFMOMA was making progress to exceed LEED Gold requirements. A building energy model for the expanded museum, including the photography storage systems and a cold vault for color photography, was prepared for this analysis. Atelier Ten also prepared a Title 24 California energy code analysis to document compliance for the project. All of the energy efficiency measures included in the project will help SFMOMA to comply with Title 24 and with the San Francisco Green Building Ordinance to exceed the energy compliance margin by 15% in the future (see Appendix C).



SFMOMA systems diagram produced by Atelier Ten

At the core of the project is an innovative energy system utilizing evaporative humidification combined with consistent set-point values for temperature and seasonally-adjusted set-point values for humidity to yield annual energy savings for the expansion of about 38% and annual energy cost savings of about 34% (compared to an ASHRAE 90.1-2007 minimally compliant baseline case, see Appendix D). LED lighting throughout the Expansion and in the existing building, which is managed by centrally-located lighting control software, contributes significantly to overall energy savings.

Water savings are also substantial. Stormwater is reused for toilet flushing, and low-flow fixtures are specified throughout. Stormwater and greywater are used for irrigation of the living wall and are also re-circulated within the wall system. These systems all contribute to the 60% decrease in potable water use in the new building. The living wall, the largest public vertical garden of its kind in the country, was designed as a subtly monochromatic green mosaic made of 19,442 plants from 38 different species, including 21 native plant species found in East Bay Regional Parks and Mount Tamalpais. These native plants used on the living wall and on other areas of the project are locally sourced and help keep water use low.

SFMOMA's living wall and building exterior

The new exterior façade is not just lightweight and sculptural – it also is a highly sophisticated energy efficient building envelope, that helps minimize energy use in the building. The fiberglass reinforced polymer panels were cast using an expanded polystyrene foam mold, which is not only an economical and recyclable material, but also served as the perfect handling cradle for the protection and safe installation of each panel.

Other notable sustainable aspects include the use of daylighting on the administrative levels in particular, reuse of salvaged wood flooring within the project, local materials where possible, and high recycled content in many of the products. This includes purchasing art storage furniture from Spacesaver, an ISI 9001 certified company committed to environmental sustainability, with implemented measures for use of recycled water, solventfree powder-coat painting, lean manufacturing, steel and aluminum recycling, and brownout participation to minimize the ecological impact of the manufacturing process.

SFMOMA extended and applied sustainable museum practices under the LEED Gold and Green Building Ordinance guidelines to maximize energy savings in the two photography storage vaults: mapping efficient floor plans; selecting art storage screens that can be installed without piercing the cold vault envelope (StabaArte); setting temperature and RH set points for cold storage; and establishing agreed-upon cold storage access protocols.

Cold Storage Vault

Study Center Storage Vault

Commissioning, Evaluation and Dissemination

The expansion of SFMOMA is on track to be LEED Gold certified in late 2016. Additionally, because the Snøhetta expansion and the Botta building are interconnected through common mechanical systems, the Botta building will also be seeing a significant reduction in energy use in addition to other sustainable upgrades.

On September 9, 2016, SFMOMA reconvened the 2012 Sustainability Roundtable specialists to recap the design and building process, assess the building's operation, and begin an ongoing process of evaluation. Participants in this roundtable included: SFMOMA conservators and building engineers, project architects, project engineers, sustainability consultants, the contractor, and relevant sub-contractors.

SFMOMA is committed to sharing the successes, challenges, and lessons of this project to its audiences and peer institutions. *Furnishing Sustainable Photography Storage* will have a lasting impact on SFMOMA and it is the museum's hope that this knowledge will also be useful for others in the future. This white paper is one of the project's five modes of dissemination, including professional outreach at the 2012 AIC Annual Meeting, 2013 AIC Annual Meeting, 2014 American Alliance of Museums Annual Meeting, and a ½ day, informal colloquium for Bay Area museum colleagues in 2015. The NEH White Paper will be sent to Bay Area museum colleagues as a follow-up to that colloquium.

In the coming years, SFMOMA plans to evaluate and disseminate information about the effectiveness of the building and storage systems for the photography collection through a formal evaluation of the operational cost savings and by monitoring the preservation of the collection to ensure its continuing access for humanities programming. This will include a reconvening of the Sustainability Roundtable specialists and as well as inviting speaking opportunities that allow the team to assess and reflect on the lessons learned.

Project Team

SFMOMA Staff

The project was led by Jill Sterrett, Director of Collections and Conservation at SFMOMA. Throughout the project, she worked closely with an interdepartmental leadership team that included photography curators, registration, senior museum preparators, photography conservators, the Collections Information and Access (CIA) team, the expansion coordinator, and the facilities team. Jill Sterrett also worked closely with Michelle Barger, the museum's Conservator of Objects, to implement the project dissemination plan.

Outside Consultants

SFMOMA worked with Snøhetta and Samuel Anderson Architects (SAA) on the design of the Cold Storage Vault and the Study Center Vault to ensure the most efficient use of the designated footprints. Atelier Ten led the environmental design evaluation while EHDD led the coordination for the LEED Gold certification. To complete this design, SFMOMA worked with Taylor Engineering and Webcor Builders, whose project team included CMI Critchfield Mechanical and commercial lighting consultant Arup.

Conclusion

Furnishing Sustainable Photography Storage was an essential component of the much larger initiative to assemble the entire photography collection in one location and to realize the Pritzker Center for Photography, the largest museum space permanently dedicated to photography in the United States.

Locating the entire photography collection on site proximate to the photography galleries, the Photography Interpretive Gallery and the Study Center ensures works are immediately availability to artists, scholars, classes and our public in ways that are consistent with the ambitions detailed in SFMOMA's 2012-2018 strategic plan. Moreover, the Cold Storage Vault and Study Center Vaults were designed to accommodate 15 years of growth, contributing to the museum's rigorous pursuit of inquiry and scholarship in the future.

Appendix A

Taylor Engineering LLC
1080 Marina Village Parkway, Suite 501 ■ Alameda, CA 94501-1142 ■ (510) 749-9135 ■ Fax (510) 749-9136

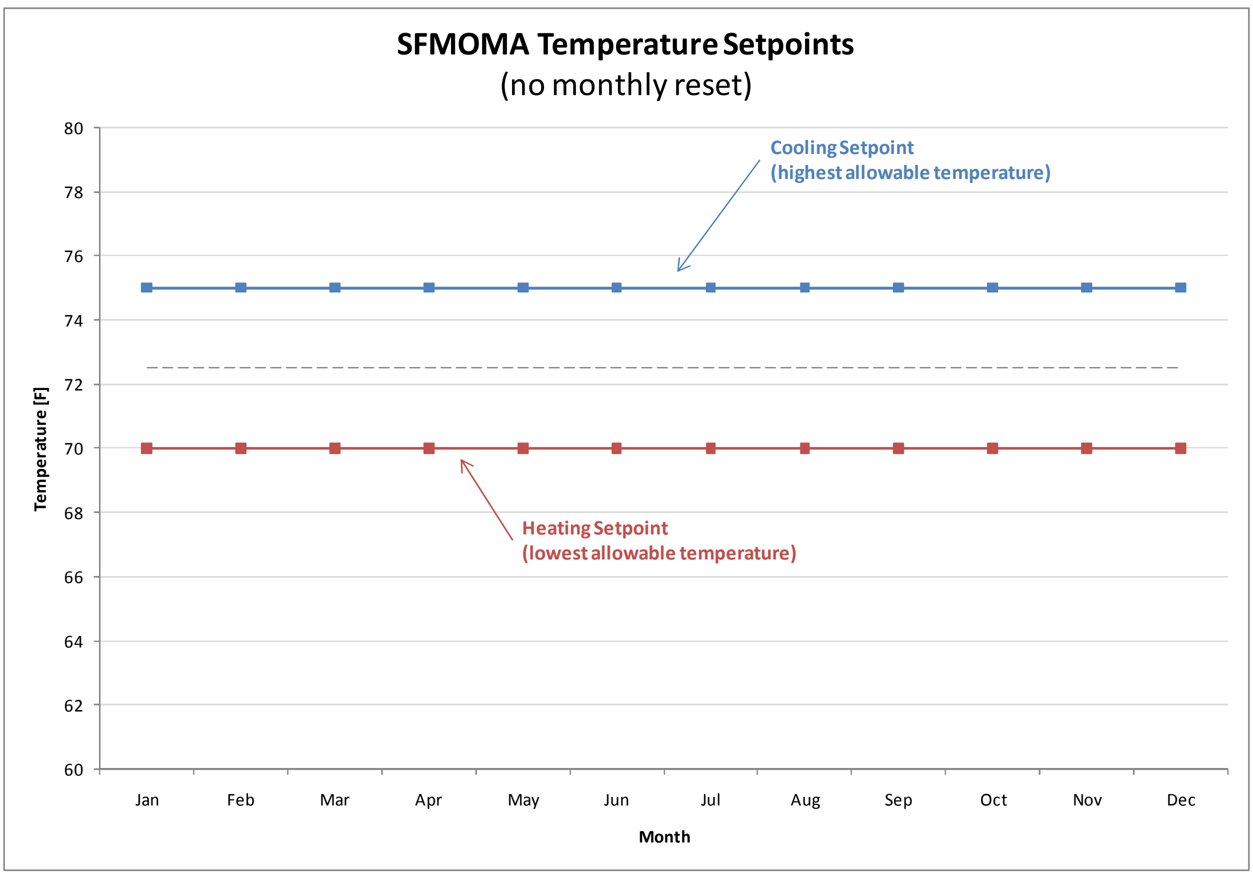
To: Simon Ewings, Snohetta Architecture
From: Allan Daly, Taylor Engineering
Subject: SFMOMA Indoor Environmental Criteria
Date: April 7, 2012

Following the decisions made at the SFMOMA Sustainability Roundtable we are adopting the following indoor environmental criteria for the design of the expansion project.

Temperature

Heating: 70F Summary: 72.5F +/- 2.5F
Cooling: 75F

These temperature setpoints are consistent across the entire year.

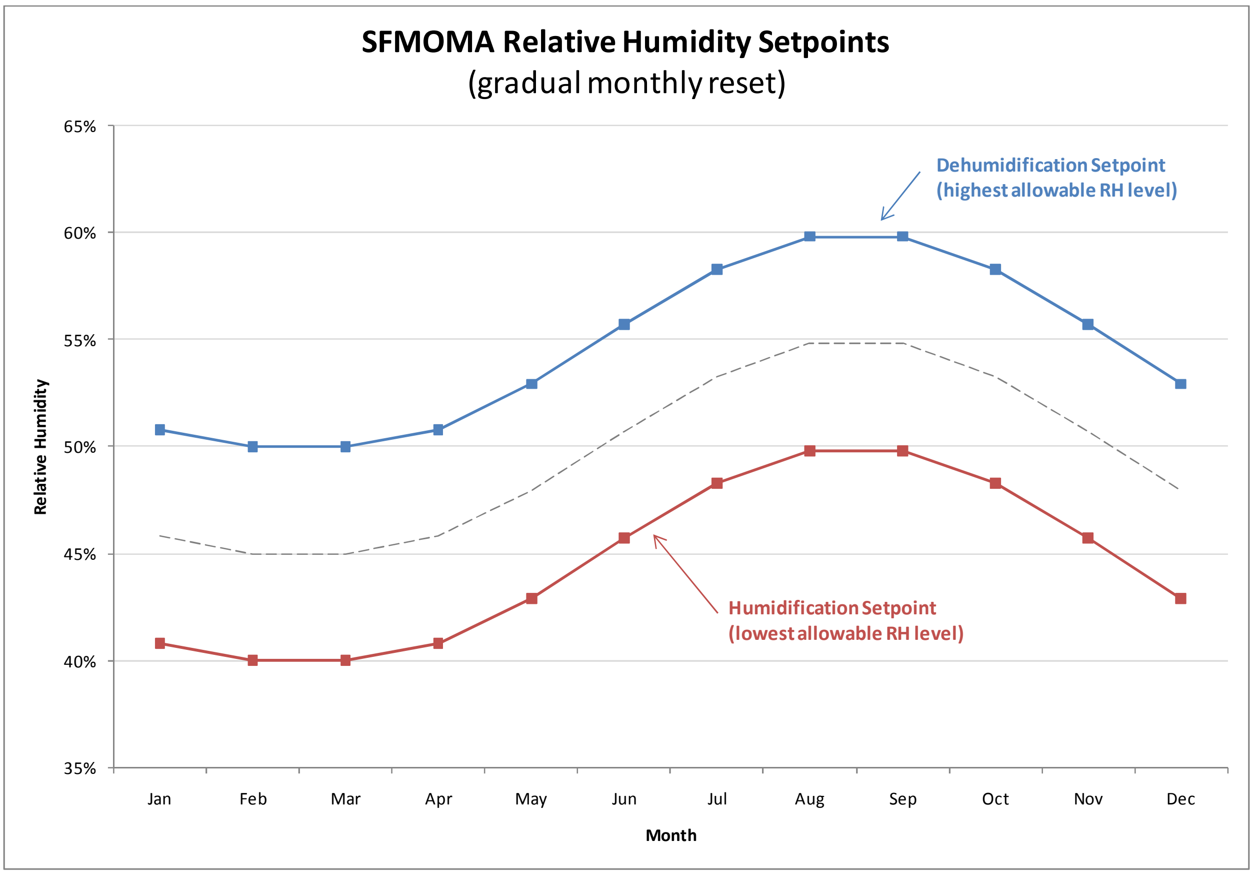


Relative Humidity

Summer:
Dehumidification: 60% Summary: 55% +/-5%
Humidification: 50%

Winter:
Dehumidification: 50% Summary: 45% +/-5%
Humidification: 40%

These temperature setpoints are gradually adjusted each month to achieve a maximum seasonal variation of 10%.



Appendix B

LUMELEX® 2044 SERIES 120/277V • LED

Elegant fixed downlight designed specifically for the most demanding architecture applications.

- Designed for an LED module up to 23 Watts in three formats: Xicato XTM (19mm), Xicato XTM (9mm), and Dim to Warm

General Features
- Tested to LM79 and LM80 Protocols, TM-30 available
- Hidden integral electronic driver compatible with reverse phase (ELV compatible) dimmers down to 5%
- Field interchangeable optics (15°- 60°) modify the beam spread distribution
- Accessory holder accepts up to two size-AA LSI filters and accessories
- Integral dimmer available
- Finishes: LSI Black, White, and Silver
- Fixture weight: 3 lbs
- All modules are field replaceable

Xicato XTM Module
- Extremely tight color consistency (less than 2 MacAdam Ellipses)
- System efficiency up to 87 lumens/watt
- Backed by Xicato's Five Year Color Consistency and Lumen Maintenance Warranty
- 50,000 hour life to 70% lumen output, L70 at 95°F max ambient
- Choice of color temperature
- Color Rendering Index (CRI) of either 98 (high) or 83 (standard)
- Color Fidelity (R_f) 96 (high) or 78 (standard)
- Gamut Area Index (R_g) 103 (high) or 101 (standard)
- Choice of lumen outputs (delivered lumens)

Dim to Warm Module
- Natural dimming that approximates the black body curve
- System efficiency up to 59 lumens/watt
- 36,000 hour life to 70% lumen output, L70 at 95°F max ambient
- Halogen mimicking color from 2800°K to 2000°K
- Color Rendering Index (CRI) of 92 min. at all dimming settings
- Color Fidelity (R_f) 92
- Gamut Area Index (R_g) 102
- Lumen output: 1800 Lumens
- Proprietary mixing optics for smooth even light

MOUNTING OPTIONS

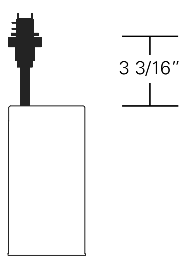
Please review the **ORDERING INFORMATION** section on the next page on how to specify the following:

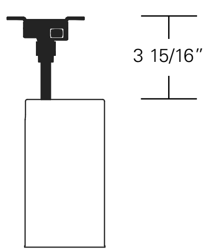
- LED Module
- LED Rating
- Color Temperature
- Optic - mm/ beam spead
- Dimming
- Voltage
- Finish

LX2044-XXXXX-XXXXXX-00-TEXXXX
Lexan fitting for 1 and 2 circuit LSI track. With On/Off switch.

LX2044-XXXXX-XXXXXX-0E-EDXXXX
Lexan fitting with integral dimmer (for use with ED dimming driver 10%).

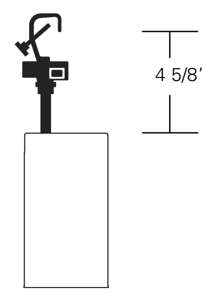
LX2044-XXXXX-XXXXXX-LT-LTXXXX
Lexan fitting with LumenTalk dimmer (for use with LT dimming driver (<1%).



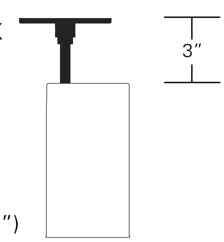


LX2044-XXXXX-XXXXXX-2G-TEXXXX
Universal fitting for Unistrut Systems and any screw or bolt-up applications. With switch, 6-foot 3-wire grounding cord and NEMA 5-15P plug.

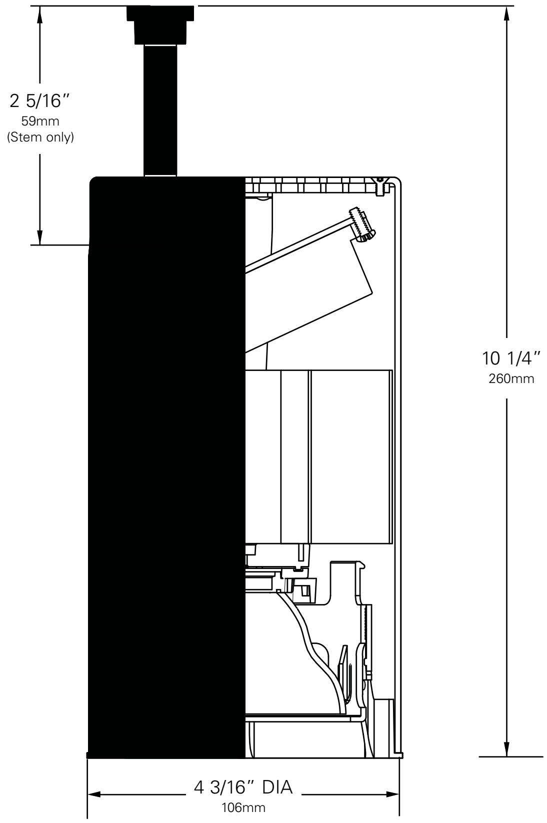
LX2044-XXXXX-XXXXXX-3G-TEXXXX
C-clamp for pipes from 5/8" to 2" O.D. With switch, 6-foot 3-wire grounding cord and NEMA 5-15P plug.



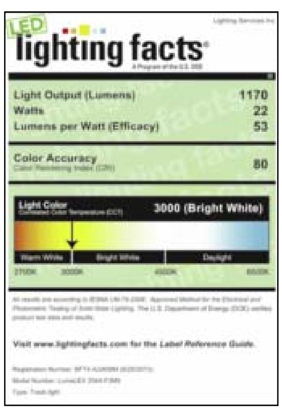
LX2044-XXXXX-XXXXXX-5A-XXXXXX
Canopy for permanent mounting on standard 4" octagonal junction boxes.



Other Options (Consult Factory):
- Custom Stems, specify length (4"- 48")
- Custom color, RAL palette
- Security/Worklite Fixture, use **—EF** as mounting option. (track mount only)



LUMELEX® 2044 LED FIXTURE DATA



Color Temperature & Center Point Tolerance

Color Temp	Center Point	Tolerance
2700K	2700K	+/- 40K
3000K	2950K	+/- 50K
3500K	3420K	+/- 60K
4000K	4000K	+/- 70K

ORDERING INFORMATION

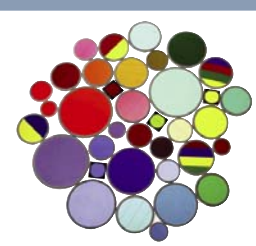
Xicato XTM 19mm Fixture

1. Choose the desired LED Module **(T19)** for XTM (19mm)
2. Choose the numeric code to designate the desired LED Rating
   Lumens/CRI/Wattage
   (10-98) for 1000/98/13 **(10-83)** for 1000/83/11
   (13-98) for 1300/98/20 **(13-83)** for 1300/83/15
   (18-98) for 1800/98/23 **(20-83)** for 2000/83/23
   (23-83) for 2300/83/23
3. Choose the numeric code to designate the desired **Color Temperature**
   (27) for 2700K **(30)** for 3000K For other CCT, consult factory
4. Use the following alpha-numeric code to designate the **Optic**
   (S1) for 50mm/15°
   (WR) for 70mm/20°(Field Reducer)
   (M2) for 70mm/20° (Narrow Field Angle)
   (M9) for 70mm/20° (Wide Field Angle)
   (M4) for 70mm/35° (Narrow Field Angle)
   (M8) for 70mm/40° (Wide Field Angle)
   (M6) for 70mm/60°
5. Select your **Mounting Option**
   (00) Track Fitting **(0E)** Track Fitting with Integral Dimmer
   (LT) Lumentalk Fitting **(2G)** Unistrut Fitting
   (3G) C-clamp Fitting **(5A)** Canopy Fitting
6. Choose other fixture Options:
   • Coiled Cord is available only with **2G** and **3G** mounting options. Change 2G to **2C** and 3G to **3C**. (When a coiled cord is not specified, a straight cord is provided.)
7. Choose the letter code for **Dimming Type:**
   (TE) Trailing Edge (Reverse Phase) (5%)
   (ED) Integral Dimming (10%) (0E & 5A fitting only)
   (LT) Lumentalk (<1%) (LT fitting only)
   (10) 0-10V (10%) (5A fitting only)
8. Choose the desired **Voltage**:
   (120) for 120V **(230)** for 220-240V **(277)** for 277V
9. Choose a **Finish** for your fixture: Black **(B)** White **(W)** Silver **(S)**

Example:	LX2044	-	T19	20-83	27	S1	-	00	-	TE	120	B
	FIXTURE		LED MODULE	LED RATING	COLOR TEMP	OPTIC		FITTING		DRIVER	VOLTAGE	FINISH

10. Don’t forget your Accessories!

ACCESSORIES



Glass Color Filters AA
As the foremost innovator in accent lighting, LSI offers a complete range of permanent fade-free glass color filters, which are available in nine stock diameters.

- **ANG Hood 2IN AA**
- **Hood 2IN AA**

*S15 optic for use with gel accessories only.

Other accessories:

- **LX-S15-REF-B* (50mm/15°)**
- **LX-WRD-REF-CLR (70mm/20°)**
- **LX-M20-REF-B (70mm/20°)**
- **LX-M90-REF-CLR (70mm/20°)**
- **LX-M40-REF-B (70mm/35°)**
- **LX-M80-REF-CLR (70mm/40°)**
- **LX-M60-REF-CLR (70mm/60°)**
- **Color and Spread Gels AA**
- **Backer Ring AAB**
- **Louver Hex AA**
- **Beam Softener AA998**
- **Lighting Blocking Screens AA801S, AA802S, AA803S**
- **Spread Lenses AA990, AA992, AA995, AA996**

LUMELEX® 2044 SERIES • XICATO XTM 19MM PERFORMANCE

The performance characteristics of the LumeLEX2000 family of products can be customized based on the LED module and the optic (reflector) selected.

Each available LED module is defined by four characteristics – the color rendering index (CRI), the correlated color temperature (CCT), the power that it uses (watts), and its "available lumens." Note that available lumens is a theoretical value that represents the light output of the module on its own – no fixture or optic attached.

In the LSI part number, the LED module is specified with a letter and a number that immediately follow the product series number. For example, in the part number LX2044-T1920-8327S1-00-TE120B, the "**T1920-8327**" represents an LED module with an output of 2000 lumens, a CRI of 83, a power usage of 23 watts and a color temperature of 2700K.

The available optics (reflectors) are characterized by size, beam angle, and in some cases the characteristics of the field angle (narrow or wide). The optic is specified by the two characters that follow the LED designation in the part number. For example, the "**S1**" in T1920-8327S1-00-TE120B is a 50mm diameter optic that has a 15-Degree beam with a narrow field.

Additional parameters, such as Center Beam Candle Power (CBCP), Delivered Lumens, and Efficiency (Lumens per Watt) are all shown in a table that is organized by LED module and optic combination.

CBCP = Center Beam Candle Power

LED Module	Optic (Reflector)						
Lumens/CRI/Wattage	**S1**	**M2**	**WR**	**M4**	**M6**	**M8**	**M9**
1000/83/11	2872	3275	2257	2439	1009	1482	3010
1000/98/13	2872	3275	2257	2439	1009	1482	3010
1300/83/15	3733	4257	2935	3171	1312	1927	3913
1300/98/20	3733	4257	2935	3171	1312	1927	3913
1800/98/23	5267	6006	4140	4473	1851	2718	5520
2000/83/23	5743	6549	4515	4878	2018	2964	6020
2300/83/23	6645	7577	5224	5644	2335	3429	6965

Delivered Lumens

LED Module	Optic (Reflector)						
Lumens/CRI/Wattage	**S1**	**M2**	**WR**	**M4**	**M6**	**M8**	**M9**
1000/83/11	313	387	342	602	864	830	856
1000/98/13	313	387	342	602	864	830	856
1300/83/15	407	503	445	783	1123	1079	1113
1300/98/20	407	503	445	783	1123	1079	1113
1800/98/23	575	709	628	1104	1584	1523	1570
2000/83/23	627	774	685	1204	1728	1660	1712
2300/83/23	725	895	792	1393	1999	1921	1981

Efficiency = Lumens Per Watt

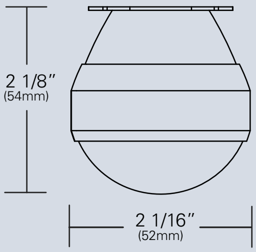
LED Module	Optic (Reflector)						
Lumens/CRI/Wattage	**S1**	**M2**	**WR**	**M4**	**M6**	**M8**	**M9**
1000/83/11	28	35	31	55	79	75	78
1000/98/13	24	30	26	46	66	64	66
1300/83/15	27	34	30	52	75	72	74
1300/98/20	20	25	22	39	56	54	56
1800/98/23	25	31	27	48	69	66	68
2000/83/23	27	34	30	52	75	72	74
2300/83/23	32	39	34	61	87	84	86

Absolute range of values are +/- 10% of typical value, and are for all color temperatures

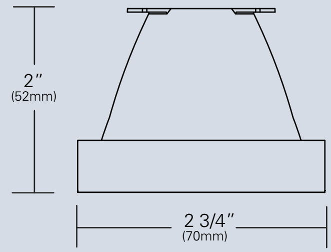
LED Module **Lumens/CRI/Wattage** **Letter Code**	**1000/83/11** **10-83**	**1000/98/13** **10-98**	**1300/83/15** **13-83**	**1300/98/20** **13-98**	**1800/98/23** **18-98**	**2000/83/23** **20-83**	**2300/83/23** **23-83**
Nominal Fixture Power (+/- 20%), Watts	11	13	15	20	23	23	23
Maximum Inrush Current Amps	10	10	10	10	10	10	10
Minimum Power Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92

Inrush current is instantaneous current drawn by the LED only when fixture is initially powered on or instantaneously changed from full dim to full bright. For more details see Dimming Application Sheet, IS-0119.

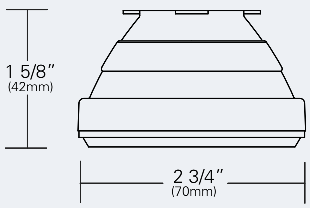
LumeLEX® 2044 SERIES • XICATO XTM 19MM OPTICS



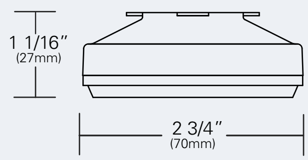
LX-S15-REF-B (S1)
(50mm/15°)
Anti-reflective coated aspheric lens. Tool-less, twist and lock installation. For use with gel accessories only.Black finish.



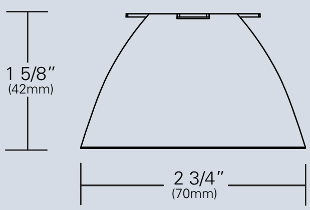
LX-WRD-REF-CLR (WR)
(70mm/20°)
Field reducer.
Proprietary field reducing baffle. Clear finish.



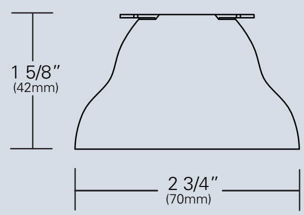
LX-M20-REF-B (M2)
(70mm/20°)
(Narrow Field Angle)
Computer designed polycarbonate lens. Tool-less, twist and lock installation. Black finish.



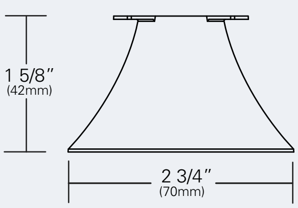
LX-M40-REF-B (M4)
(70mm/35°)
(Narrow Field Angle)
Computer designed polycarbonate specular optic. Tool-less, twist and lock installation. Black finish.



LX-M90-REF-CLR (M9)
(70mm/20°)
(Wide Field Angle)
Computer designed polycarbonate specular optic. Tool-less, twist and lock installation.Clear finish.



LX-M80-REF-CLR (M8)
(70mm/40°)
(Wide Field Angle)
Computer designed polycarbonate specular optic. Tool-less, twist and lock installation. Clear finish.



LX-M60-REF-CLR (M6)
(70mm/60°)
Computer designed polycarbonate specular optic. Tool-less, twist and lock installation. Clear finish.

LUMELEX® 2044 SERIES • XICATO XTM 19MM PHOTOMETRIC DATA

LED RATING: 13-98

S1- 50mm DIA Optic
Beam Spread (minimum) **15°**
Center Beam Candlepower **3733**
CRI **98**

M2- 70mm DIA Optic
(NFA: Narrow Field Angle)
Beam Spread (minimum) **20°**
Center Beam Candlepower **4257**
CRI **98**

WR- 70mm DIA Optic
(FR: Field Reducer)
Beam Spread (minimum) **20°**
Center Beam Candlepower **3193**
CRI **98**

M4- 70mm DIA Optic
(NFA: Narrow Field Angle)
Beam Spread (minimum) **35°**
Center Beam Candlepower **3171**
CRI **98**

M6- 70mm DIA Optic
(NFA: Narrow Field Angle)
Beam Spread (minimum) **60°**
Center Beam Candlepower **1312**
CRI **98**

M8- 70mm DIA Optic
(WFA: Wide Field Angle)
Beam Spread (minimum) **40°**
Center Beam Candlepower **1927**
CRI **98**

M9- 70mm DIA Optic
(WFA: Wide Field Angle)
Beam Spread (minimum) **20°**
Center Beam Candlepower **3913**
CRI **98**

LED RATING: 20-83

S1- 50mm DIA Optic
Beam Spread (minimum) **15°**
Center Beam Candlepower **5743**
CRI **83**

M2- 70mm DIA Optic
(NFA: Narrow Field Angle)
Beam Spread (minimum) **20°**
Center Beam Candlepower **6549**
CRI **83**

WR- 70mm DIA Optic
(FR: Field Reducer)
Beam Spread (minimum) **20°**
Center Beam Candlepower **4912**
CRI **83**

M4- 70mm DIA Optic
(NFA: Narrow Field Angle)
Beam Spread (minimum) **35°**
Center Beam Candlepower **4878**
CRI **83**

M6- 70mm DIA Optic
(NFA: Narrow Field Angle)
Beam Spread (minimum) **60°**
Center Beam Candlepower **2018**
CRI **83**

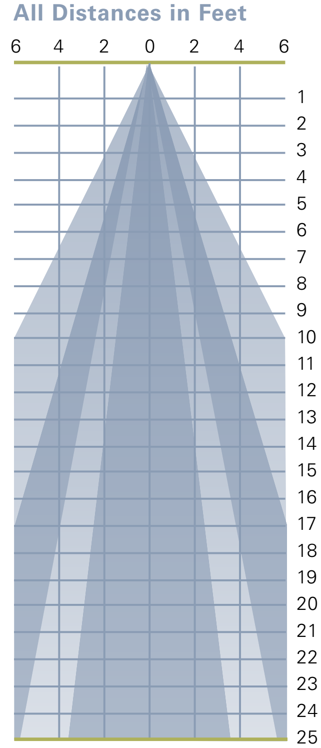
M8- 70mm DIA Optic
(WFA: Wide Field Angle)
Beam Spread (minimum) **40°**
Center Beam Candlepower **2964**
CRI **83**

M9- 70mm DIA Optic
(WFA: Wide Field Angle)
Beam Spread (minimum) **20°**
Center Beam Candlepower **6020**
CRI **83**

LED RATING: 13-98

All Max. Footcandles at 0° Beam Axis

M6 (60°) NFA	M8 (40°) WFA	M4 (35°) NFA	M9 (20°) WFA	WR (20°) FR	M2 (20°) NFA	S1 (15°)
1312	1927	3171	3913	3193	4257	3733
328	482	793	978	798	1064	933
146	214	352	435	355	473	415
82	120	198	245	200	266	233
52	77	127	157	128	170	149
36	54	88	109	89	118	104
27	39	65	80	65	87	76
21	30	50	61	50	67	58
16	24	39	48	39	53	46
13	19	32	39	32	43	37
11	16	26	32	26	35	31
9	13	22	27	22	30	26
8	11	19	23	19	25	22
7	10	16	20	16	22	19
6	9	14	17	14	19	17
5	8	12	15	12	17	15
5	7	11	14	11	15	13
4	6	10	12	10	13	12
4	5	9	11	9	12	10
3	5	8	10	8	11	9
3	4	7	9	7	10	8
3	4	7	8	7	9	8
2	4	6	7	6	8	7
2	3	6	7	6	7	6
2	3	5	6	5	7	6

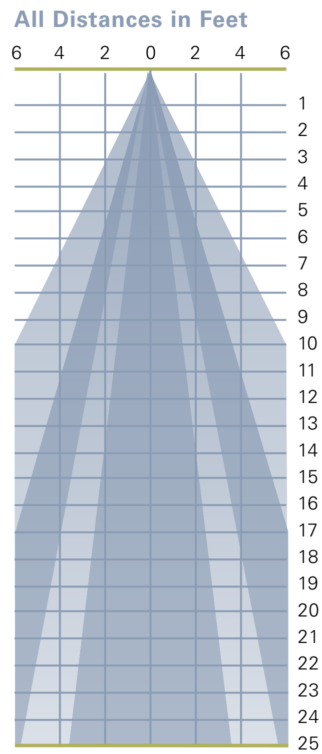


Photometric Data based on LED Rating: 13-98 (1300 Lumens/98CRI/20watts)
*WFA Optics not represented in graph

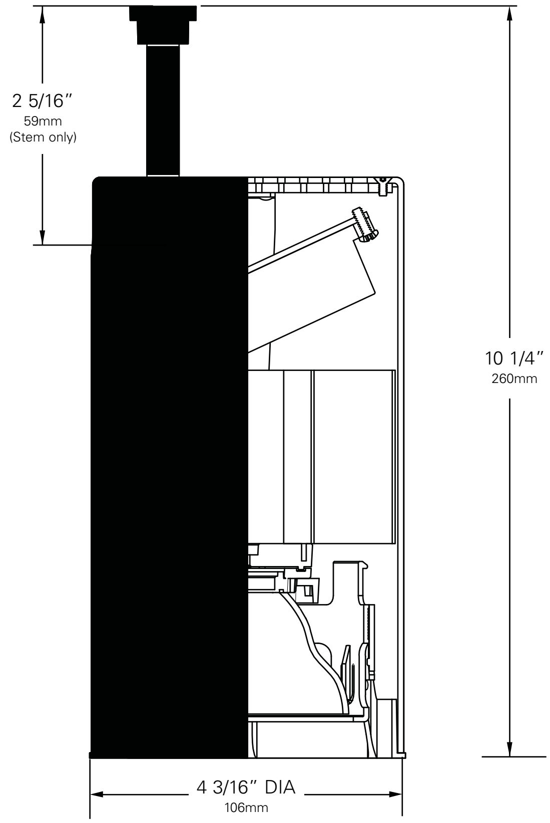
LED RATING: 20-83

All Max. Footcandles at 0° Beam Axis

M6 (60°) NFA	M8 (40°) WFA	M4 (35°) NFA	M9 (20°) WFA	WR (20°) FR	M2 (20°) NFA	S1 (15°)
2018	2964	4878	6020	4912	6549	5743
505	741	1220	1505	1228	1637	1436
224	329	542	669	546	728	638
126	185	305	376	307	409	359
81	119	195	241	196	262	230
56	82	136	167	136	182	160
41	60	100	123	100	134	117
32	46	76	94	77	102	90
25	37	60	74	61	81	71
20	30	49	60	49	65	57
17	24	40	50	41	54	47
14	21	34	42	34	45	40
12	18	29	36	29	39	34
10	15	25	31	25	33	29
9	13	22	27	22	29	26
8	12	19	24	19	26	22
7	10	17	21	17	23	20
6	9	15	19	15	20	18
6	8	14	17	14	18	16
5	7	12	15	12	16	14
5	7	11	14	11	15	13
4	6	10	12	10	14	12
4	6	9	11	9	12	11
4	5	8	10	9	11	10
3	5	8	10	8	10	9



Photometric Data based on LED Rating: 20-83 (2000 Lumens/83CRI/23watts)
*WFA Optics not represented in graph



ORDERING INFORMATION

Xicato XTM 9mm Fixture

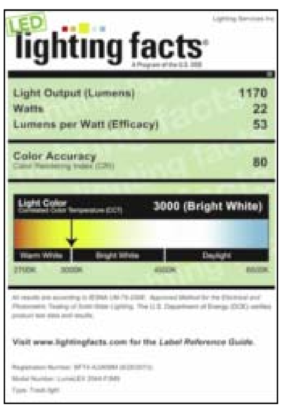
1. Choose the desired LED Module **(TS9)** for XTM (9mm)
2. Choose the numeric code to designate the desired LED Rating
   Lumens/CRI/Wattage
   (06-98) for 600/98/13 **(09-83)** for 900/83/14
   (09-98) for 900/98/22 **(13-83)** for 1300/83/22
3. Choose the code to designate the desired
   Color Temperature
   (27) for 2700K **(30)** for 3000K
   For other CCT, consult factory
4. Use the following alpha-numeric code to designate the **Optic**
   (N1) for 70mm/10°
   (NR) for 70mm/10°(Field Reducer)
   (N2) for 70mm/20°
   (N4) for 70mm/40°
   (N6) for 70mm/60°
5. Select your **Mounting Option**
   (00) Track Fitting **(0E)** Track Fitting with Integral Dimmer
   (LT) Lumentalk Fitting **(2G)** Unistrut Fitting
   (3G) C-clamp Fitting **(5A)** Canopy Fitting
6. Choose other fixture Options:
   • Coiled Cord is available only with **2G** and **3G** mounting options. Change 2G to **2C** and 3G to **3C**. (When a coiled cord is not specified, a straight cord is provided.)
7. Choose the letter code for **Dimming Type:**
   (TE) Trailing Edge (Reverse Phase) (5%)
   (ED) Integral Dimming (10%) (0E & 5A fitting only)
   (LT) Lumentalk (<1%) (LT fitting only)
   (10) 0-10V (10%) (5A fitting only)
8. Choose the desired **Voltage**:
   (120) for 120V **(230)** for 220-240V **(277)** for 277V
9. Choose a **Finish** for your fixture:
   Black **(B)** White **(W)** Silver **(S)**

Example: **LX2044** - **TS9** **13-83** **27** **N1** - **00** - **TE** **120** **B**

FIXTURE	LED MODULE	LED RATING	COLOR TEMP	OPTIC	FITTING	DRIVER	VOLTAGE	FINISH
LX2044	TS9	13-83	27	N1	00	TE	120	B

10. Don't forget your Accessories!

LUMELEX® 2044 LED FIXTURE DATA


LED lighting facts®

Light Output (Lumens)	1170
Watts	22
Lumens per Watt (Efficacy)	53
Color Accuracy	80

Light Color 3000 (Bright White)

Warm White Bright White Daylight

Visit www.lightingfacts.com for the Label Reference Guide.

Color Temperature & Center Point Tolerance

Color Temp	Center Point	Tolerance
2700K	2700K	+/- 40K
3000K	2950K	+/- 50K
3500K	3420K	+/- 60K
4000K	4000K	+/- 70K

ACCESSORIES

- **ANG Hood 2IN AA**
- **Backer Ring AAB**
- **Louver Hex AA**
- **Glass Color Filters AA**
- **Spread Lens AA990, AA992, AA995, AA996**
- **Beam Softener AA998**
- **Light Blocking Screens AA801S, AA802S, AA803S**
- **Color and Spread Gels AA**
- **LX-N10-REF-CLR (70mm/10°)**
- **LX-NRD-REF-CLR (70mm/10°) Field Reducer**
- **LX-N20-REF-CLR (70mm/20°)**
- **LX-N40-REF-CLR (70mm/40°)**
- **LX-N60-REF-CLR (70mm/60°)**

LUMELEX® 2044 SERIES • XICATO XTM 9MM PERFORMANCE

The performance characteristics of the LumeLEX2000 family of products can be customized based on the LED module and the optic (reflector) selected.

Each available LED module is defined by four characteristics – the color rendering index (CRI), the correlated color temperature (CCT), the power that it uses (watts), and its "available lumens." Note that available lumens is a theoretical value that represents the light output of the module on its own – no fixture or optic attached.

In the LSI part number, the LED module is specified with a letter and a number that immediately follow the product series number. For example, in the part number LX2044-TS913-8327N1-00-TE120B, the "**TS913-8327**" represents an LED module with an output of 1300 lumens, a CRI of 83, a power usage of 22 watts and a color temperature of 2700K.

The available optics (reflectors) are characterized by size, beam angle, and in some cases the characteristics of the field angle (narrow or wide). The optic is specified by the two characters that follow the LED designation in the part number. For example, the "**N1**" in TS913-8327N1 is a 70mm diameter optic that has a 10-Degree beam.

Additional parameters, such as Center Beam Candle Power (CBCP), Delivered Lumens, and Efficiency (Lumens per Watt) are all shown in a table that is organized by LED module and optic combination.

CBCP = Center Beam Candle Power

LED Module	Optic (Reflector)				
Lumens/CRI/Wattage	**N1**	**NR**	**N2**	**N4**	**N6**
600/98/13	7338	5346	1590	948	576
900/83/14	11007	8019	2385	1422	864
900/98/22	11007	8019	2385	1422	864
1300/83/22	15899	11583	3445	2054	1248

Delivered Lumens

LED Module	Optic (Reflector)				
Lumens/CRI/Wattage	**N1**	**NR**	**N2**	**N4**	**N6**
600/98/13	468	186	438	462	444
900/83/14	702	279	657	693	666
900/98/22	702	279	657	693	666
1300/83/22	1014	403	949	1001	962

Efficiency = Lumens Per Watt

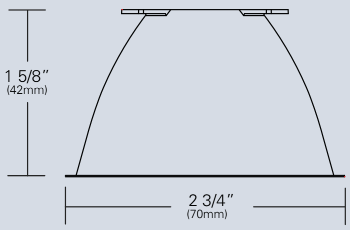
LED Module	Optic (Reflector)				
Lumens/CRI/Wattage	**N1**	**NR**	**N2**	**N4**	**N6**
600/98/13	36	14	34	36	34
900/83/14	50	20	47	50	48
900/98/22	32	13	30	32	30
1300/83/22	46	18	43	46	44

Absolute range of values are +/- 10% of typical value, and are for all color temperatures

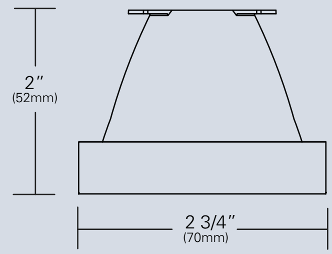
LED Module **Lumens/CRI/Wattage** **Letter Code**	**600/98/13** **06-98**	**900/83/14** **09-83**	**900/98/22** **09-98**	**1300/83/22** **13-83**
Nominal Fixture Power (+/- 20%), Watts	13	14	22	22
Maximum Inrush Current Amps	10	10	10	10
Minimum Power Factor	0.92	0.92	0.92	0.92

Inrush current is instantaneous current drawn by the LED only when fixture is initially powered on or instantaneously changed from full dim to full bright. For more details see Dimming Application Sheet, IS-0119.

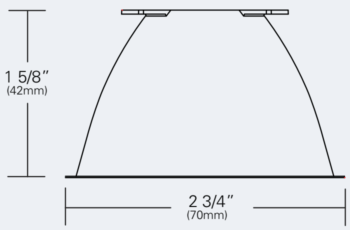
LumeLEX® 2044 SERIES • XICATO XTM 9MM OPTICS



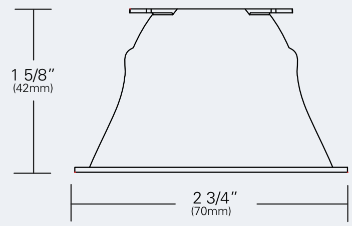
LX-N10-REF-CLR (N1) (70mm/10°)
Faceted reflectively coated metal optic. Tool-less twist and lock installation. Clear finish.



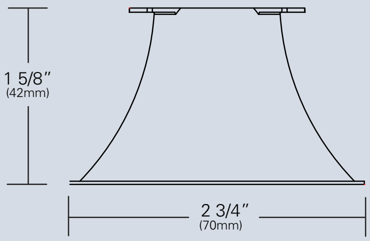
LX-NRD-REF-CLR (NR) (70mm/10°)
Field reducer. Proprietary field reducing baffle. Clear finish.



LX-N20-REF-CLR (N2) (70mm/20°)
Faceted reflectively coated metal optic. Tool-less twist and lock installation. Clear finish.



LX-N40-REF-CLR (N4) (70mm/40°)
Faceted reflectively coated metal optic. Tool-less twist and lock installation. Clear finish.



LX-N60-REF-CLR (N6) (70mm/60°)
Faceted reflectively coated metal optic. Tool-less twist and lock installation. Clear finish.

LUMELEX® 2044 SERIES • XICATO XTM 9MM PHOTOMETRIC DATA

LED RATING: 06-98

N1- 50mm DIA Optic
Beam Spread (minimum) **10°**
Center Beam Candlepower **7338**
CRI **98**

NR- 70mm DIA Optic
(FR: Field Reducer)
Beam Spread (minimum) **10°**
Center Beam Candlepower **5346**
CRI **98**

N2- 70mm DIA Optic
Beam Spread (minimum) **20°**
Center Beam Candlepower **1590**
CRI **98**

N4- 70mm DIA Optic
Beam Spread (minimum) **40°**
Center Beam Candlepower **948**
CRI **98**

N6- 70mm DIA Optic
Beam Spread (minimum) **60°**
Center Beam Candlepower **576**
CRI **98**

LED RATING: 13-83

N1- 70mm DIA Optic
Beam Spread (minimum) **10°**
Center Beam Candlepower **15899**
CRI **83**

NR- 70mm DIA Optic
(FR: Field Reducer)
Beam Spread (minimum) **10°**
Center Beam Candlepower **11583**
CRI **83**

N2- 70mm DIA Optic
Beam Spread (minimum) **20°**
Center Beam Candlepower **3445**
CRI **83**

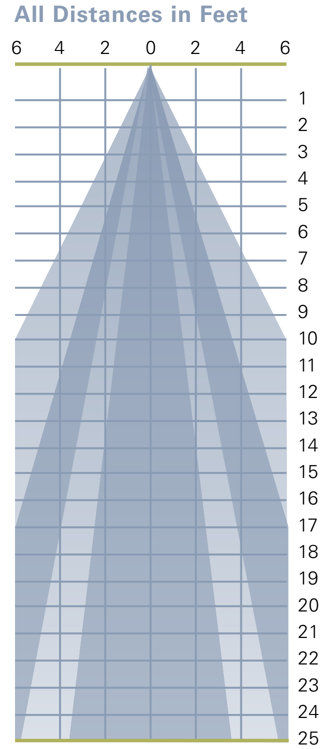
N4- 70mm DIA Optic
Beam Spread (minimum) **40°**
Center Beam Candlepower **2054**
CRI **83**

N6- 70mm DIA Optic
Beam Spread (minimum) **20°**
Center Beam Candlepower **1248**
CRI **83**

LED RATING: 06-98

All Max. Footcandles at 0° Beam Axis

N6 (60°)	N4 (40°)	N2 (20°)	NR (10°) FR	N1 (10°)
576	948	1590	5346	7338
144	237	398	1337	1835
64	105	177	594	815
36	59	99	334	459
23	38	64	214	294
16	26	44	149	204
12	19	32	109	150
9	15	25	84	115
7	12	20	66	91
6	9	16	53	73
5	8	13	44	61
4	7	11	37	51
3	6	9	32	43
3	5	8	27	37
3	4	7	24	33
2	4	6	21	29
2	3	6	18	25
2	3	5	17	23
2	3	4	15	20
1	2	4	13	18
1	2	4	12	17
1	2	3	11	15
1	2	3	10	14
1	2	3	9	13
1	2	3	9	12

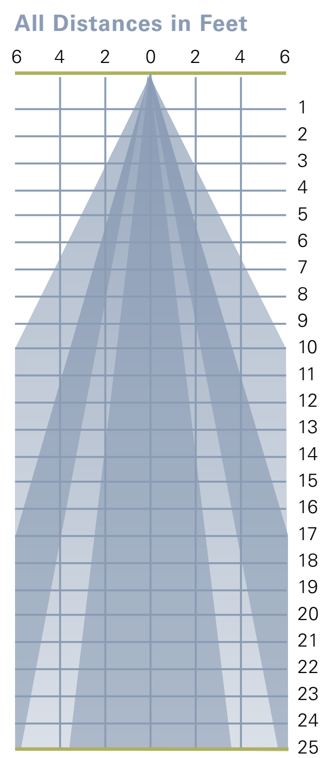


Photometric Data based on LED Rating: 06-98 (600 Lumens/98CRI/13watts)

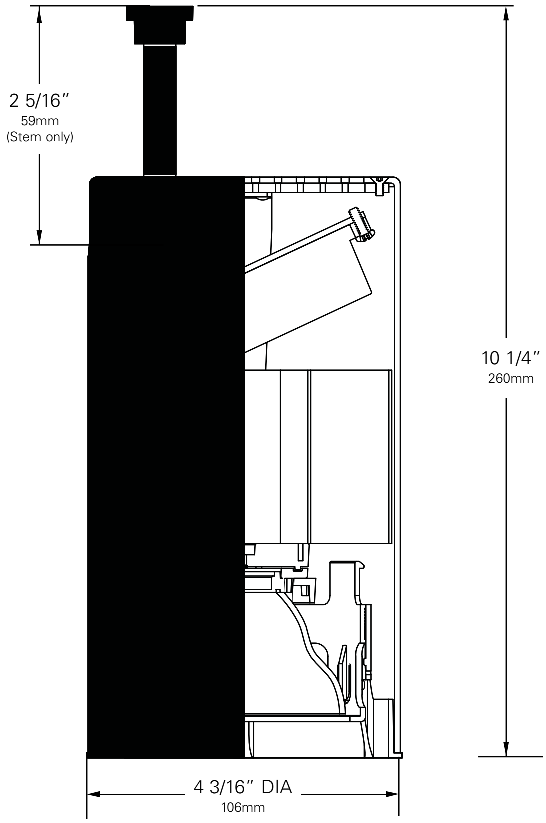
LED RATING: 13-83

All Max. Footcandles at 0° Beam Axis

N6 (60°)	N4 (40°)	N2 (20°)	NR (10°) FR	N1 (10°)
1248	2054	3445	11583	15899
514	514	861	2896	3975
228	228	383	1287	1767
128	128	215	724	994
82	82	138	463	636
57	57	96	322	442
42	42	70	236	324
32	32	54	181	248
25	25	43	143	196
21	21	34	116	159
17	17	28	96	131
14	14	24	80	110
12	12	20	69	94
10	10	18	59	81
9	9	15	51	71
8	8	13	45	62
7	7	12	40	55
6	6	11	36	49
6	6	10	32	44
5	5	9	29	40
5	5	8	26	36
4	4	7	24	33
4	4	7	22	30
4	4	6	20	28
3	3	6	19	25



Photometric Data based on LED Rating: 13-83 (1300 Lumens/83CRI/22watts)



ORDERING INFORMATION

Dim to Warm Fixture

1. Choose the desired LED Module **(D15)** for Dim to Warm (15mm)
2. Choose the numeric code to designate the desired LED Rating **Lumens/CRI/Wattage**
   (18-92) for 1800/92/22
3. Choose the code to designate the desired **Color Temperature**
   (DW) for 2800K to 2000K
4. Use the following alpha-numeric code to designate the **Optic**
   (W2) for 72mm/20° **(WR)** for 70mm/20°(Field Reducer)
   (W3) for 72mm/30° **(W4)** for 72mm/40°
   (W5) for 72mm/50°
5. Select your **Mounting Option**
   (00) Track Fitting **(0E)** Track Fitting with Integral Dimmer
   (LT) Lumentalk Fitting **(2G)** Unistrut Fitting
   (3G) C-clamp Fitting **(5A)** Canopy Fitting
6. Choose other fixture Options:
   • Coiled Cord is available only with **2G** and **3G** mounting options. Change 2G to **2C** and 3G to **3C**. (When a coiled cord is not specified, a straight cord is provided.)
7. Choose the letter code for **Dimming Type:**
   (TE) Trailing Edge (Reverse Phase) (5%)
   (ED) Integral Dimming (10%) (0E & 5A fitting only)
   (LT) Lumentalk (<1%) (LT fitting only)
   (10) 0-10V (10%) (5A fitting only)
8. Choose the desired **Voltage**:
   (120) for 120V **(230)** for 220-240V **(277)** for 277V
9. Choose a **Finish** for your fixture:
   Black **(B)** White **(W)** Silver **(S)**

Example:	LX2044	- D15	18-92	DW	W2 -	00 -	TE	120	B
	FIXTURE	LED MODULE	LED RATING	COLOR TEMP	OPTIC	FITTING	DRIVER	VOLTAGE	FINISH

10. Don't forget your Accessories!

ACCESSORIES

- ANG Hood 2IN AA
- Hood 2IN AA
- Glass Color Filters AA
- Color and Spread Gels AA
- Backer Ring AAB
- Louver Hex AA
- Beam Softener AA998
- Lighting Blocking Screens AA801S, AA802S, AA803S
- Spread Lenses AA990,AA992, AA995, AA996
- LX-W20-REF-CLR (72mm/20°)
- LX-W30-REF-CLR (72mm/30°)
- LX-W40-REF-CLR (72mm/40°)
- LX-W50-REF-CLR (72mm/50°)
- LX-WRD-REF-CLR (70mm/20°) Field Reducer

LUMELEX® 2044 SERIES • DIM TO WARM PERFORMANCE

The performance characteristics of the Dim to Warm LumeLEX2000 family of products can be customized based on the optic (reflector) selected.

The behavior of the Dim to Warm modules links the color of the light to the dimmed output of the fixture just like a halogen or incandescent source. Therefore the four characteristics defining the color — the color rendering index (CRI), the correlated color temperature (CCT) range, the power that it uses (watts), and its "available lumens" – are linked to the dim setting. Note that available lumens is a theoretical value that represents the light output of the module on its own – no fixture or optic attached. Also note that the CRI of this fixture is a minimum of 92 at any dimming setting.

In the LSI part number, the LED module is specified with a letter and a number that immediately follow the product series number. For example, in the part number LX2044-D1518-92DWW2-00-TE120B, the **"D1518-92DW"** represents a Dim to Warm LED module with an output of 1800 lumens, a CRI of 92, a power usage of 22 watts and a color temperature range of 2800K – 2000K that is tied to the dimming setting.

The available optics (reflectors) are characterized by size, beam angle, and in some cases the characteristics of the field angle (narrow or wide). The optic is specified by the two characters that follow the LED designation in the part number. For example, the **"W2"** in LX2044-D1518-92DWW2-00-TE120B is a 70mm diameter optic that has a 20-Degree beam.

Additional parameters, such as Center Beam Candle Power (CBCP), Delivered Lumens, and Efficiency (Lumens per Watt) are all shown in a table that is organized by LED module and optic combination.

CBCP = Center Beam Candle Power

LED Module	Optic (Reflector)				
Lumens/CRI/Wattage	**W2**	**WR**	**W3**	**W4**	**W5**
1800/92/22	7350	5512	4201	2991	2292

Delivered Lumens

LED Module	Optic (Reflector)				
Lumens/CRI/Wattage	**W2**	**WR**	**W3**	**W4**	**W5**
1800/92/22	1265	506	1212	1226	1305

Efficiency = Lumens Per Watt

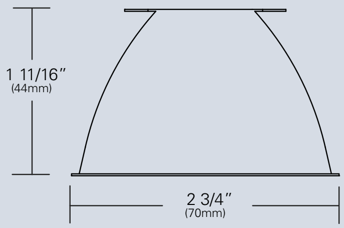
LED Module	Optic (Reflector)				
Lumens/CRI/Wattage	**W2**	**WR**	**W3**	**W4**	**W5**
1800/92/22	57	23	55	56	59

Absolute range of values are +/- 10% of typical value, and are for all color temperatures

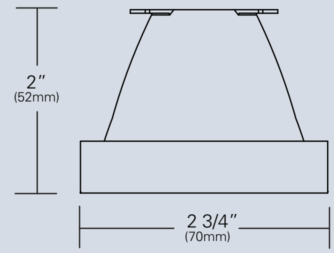
LED Module **Lumens/CRI/Wattage** **SKU Code**	**1800/92/22** **18-92**
Nominal Fixture Power (+/- 20%), Watts	22
Maximum Inrush Current Amps	10
Minimum Power Factor	0.92

Inrush current is instantaneous current drawn by the LED only when fixture is initially powered on or instantaneously changed from full dim to full bright. For more details see Dimming Application Sheet, IS-0119.

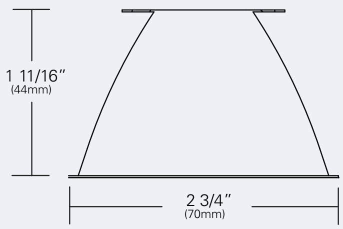
LUMELEX® 2044 SERIES • DIM TO WARM OPTICS



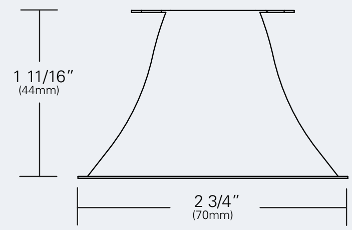
LX-W20-REF-CLR (W2) (72mm/20°)
Faceted reflectively coated metal optic. Tool-less twist and lock installation.
Clear finish.



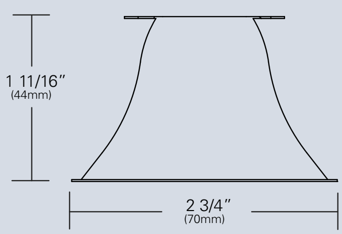
LX-WRD-REF-CLR (WR) (70mm/20°)
Field reducer.
Proprietary field reducing baffle. Clear finish.



LX-W30-REF-CLR (W3) (72mm/30°)
Faceted reflectively coated metal optic. Tool-less twist and lock installation.
Clear finish.



LX-W40-REF-CLR (W4) (72mm/40°)
Faceted reflectively coated metal optic. Tool-less twist and lock installation.
Clear finish.



LX-W50-REF-CLR (W5) (72mm/50°)
Faceted reflectively coated metal optic. Tool-less twist and lock installation.
Clear finish.

LUMELEX® 2044 SERIES • DIM TO WARM PHOTOMETRIC DATA

LED RATING: 18-92

W2-72mm DIA Optic

Beam Spread (minimum)	**20°**
Center Beam Candlepower	**7350**
CRI	**92**

WR-70mm DIA Optic

Beam Spread (minimum) (FR: Field Reducer)	**20°**
Center Beam Candlepower	**5572**
CRI	**92**

W3-72mm DIA Optic

Beam Spread (minimum)	**30°**
Center Beam Candlepower	**4201**
CRI	**92**

W4-72mm DIA Optic

Beam Spread (minimum)	**40°**
Center Beam Candlepower	**2991**
CRI	**92**

W5-72mm DIA Optic

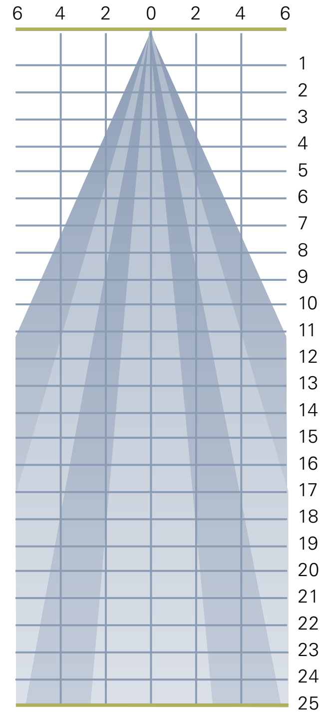
Beam Spread (minimum)	**50°**
Center Beam Candlepower	**2292**
CRI	**92**

LED RATING: 25-92

All Max. Footcandles at 0° Beam Axis

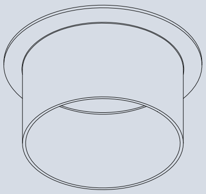
W5 (50°)	W4 (40°)	W3 (30°)	WR (20°) FR	W2 (20°)
2292	2991	4201	5572	7350
573	748	1050	1393	1838
255	332	467	619	817
143	187	263	348	459
92	120	168	223	294
64	83	117	155	204
47	61	86	114	150
36	47	66	87	115
28	37	52	69	91
23	30	42	56	74
19	25	35	46	61
16	21	29	39	51
14	18	25	33	43
12	15	21	28	38
10	13	19	25	33
9	12	16	22	29
8	10	15	19	25
7	9	13	17	23
6	8	12	15	20
6	7	11	14	18
5	7	10	13	17
5	6	9	12	15
4	6	8	11	14
4	5	7	10	13
4	5	7	9	12

All Distances in Feet



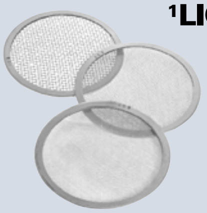
Photometric Data based on LED Rating: 18-92 (1800 Lumens/92CRI/22watts)

LUMELEX 2044 • ACCESSORIES



HOOD 2IN AA

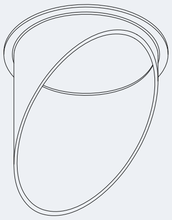
2 inch deep hood



[1]LIGHT BLOCKING SCREENS AA

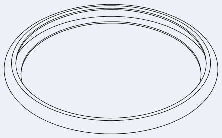
Stainless steel mesh screens used alone or in combinations will block from approximately 20% to 90% of the transmitted light without changing color temperature of the light

No.	% of Light Blocked
AA801S	20
AA802S	30
AA803S	40



ANG HOOD 2IN AA

2 inch deep angled hood



BACKER RING AA

Stainless steel ring to hold gel when no other size AA accessories is being used.

SPREAD LENSES AND BEAM SOFTENER

No.	Description	% of Light Transmission
990	Spread Lens/Clear	83 (5°X 50°)
992	Spread Lens/Clear	85 (5°X 30°)
995	Spread Lens/Clear	83 (50°X 50°)
996	Spread Lens/Clear	86 (45°X 50°)
998	Beam Softener/Clear	80 (45°X 45°)

LOUVER HEX AA

1/8” thick Hexcell black metal louver used for thin profile.

1. Figures vary based upon LED Module/Optic being used and relationship of screen(s) to LED Module/Optic and to each other.

LUMELEX® 2044 SERIES • GELS

As the foremost innovator in accent lighting, LSI offers a complete range of pre-cut Gels to modify the spread and color of light for the LumeLEX LED Series.

LumeLEX® SPREAD GELS

Size: AA (76 mm diameter)	Spread Gel
GEL-L1-AA	1° Spread Gel
GEL-L5-AA	5° Spread Gel
GEL-L10-AA	10° Spread Gel
GEL-L20-AA	20° Spread Gel
GEL-L30-AA	30° Spread Gel
GEL-L40-AA	40° Spread Gel
GEL-L60-AA	60° Spread Gel
GEL-L80-AA	80° Spread Gel
GEL-L30B5-AA	30° by 5° Spread Gel
GEL-L40B2-AA	40° by 0.2° Spread Gel
GEL-L60B1-AA	60° by 1° Spread Gel
GEL-L60B10-AA	60° by 10° Spread Gel
GEL-L75B45-AA	75° by 45° Spread Gel
GEL-L90B60-AA	90° by 60° Spread Gel
GEL-R101-AA	Beam Softener

LumeLEX® COLOR GELS

Size: AA (76 mm diameter)	Gel Color	Size: AA (76 mm diameter)	Gel Color
GEL-R2-AA	Bastard Amber	GEL-R312-AA	Canary
GEL-R7-AA	Pale Yellow	GEL-R3204-AA	Half Blue
GEL-R12-AA	Straw	GEL-R331-AA	Shell Pink
GEL-R13-AA	Straw Tint	GEL-R383-AA	Sapphire Blue
GEL-R14-AA	Medium Straw	GEL-R397-AA	Pale Grey
GEL-R21-AA	Golden Amber	GEL-R2001-AA	Storaro Red
GEL-R25-AA	Orange Red	GEL-R2004-AA	Storaro Green
GEL-R26-AA	Light Red	GEL-R2009-AA	Storaro Violet
GEL-R27-AA	Medium Red	GEL-R3202-AA	Full Blue
GEL-R57-AA	Lavender	GEL-R3206-AA	Third Blue
GEL-R62-AA	Booster Blue	GEL-R3216-AA	Eighth Blue (Boosts 3200K to 3300K)
GEL-R71-AA	Sea Blue	GEL-R3318-AA	Tough 1/8 Minusgreen
GEL-R72-AA	Azure Blue	GEL-R3410-AA	Roscosun (1/8 CTO) (Reduces 5500K to 4900K)
GEL-R91-AA	Primary Green	GEL-R3441-AA	Full Straw (CTS)
GEL-R97-AA	Light Grey	GEL-R3443-AA	Quarter Straw (CTS)
GEL-R98-AA	Medium Grey	GEL-R4330-AA	CalColor 30 Cyan
GEL-R101-AA	Light Frost	GEL-R4415-AA	CalColor 15 Green
GEL-R104-AA	Tough Silk	GEL-R4490-AA	CalColor 90 Green
GEL-R119-AA	Light Hamburg Frost	GEL-R4860-AA	CalColor 60 Pink
GEL-R121-AA	Blue Diffusion	GEL-R4890-AA	CalColor 90 Pink
GEL-R305-AA	Rose Gold	GEL-R4930-AA	CalColor 30 Lavender

* Backer Ring AAB required to hold gels when no other rimmed “AA” accesories are used.

COLOR MEDIA

COLOR FILTERS

As the foremost innovator in accent lighting, LSI offers a complete range of permanent fade-free glass color filters, which are available in nine stock diameters. All glass color filters are rimmed in a seamless aluminum ring and are slotted for heat expansion.

Size	Diameter	LSI Fixture Series
AAA	2 3/8″	LumeLEX® 2020/2030/2031/2038, SSLGR16, LumeLEX MAR
AA	3″	LumeLEX® 2024 (with LX2024-Holder or LX2024-Barndoor), LumeLEX® 2026, LumeLEX® 2044, LumeLEX 2048
A	3 1/2″	LumeLEX® 2060, SSL230, SSLGR30CL, SSLGR36
C	4 3/4″	SSL238, SSLGR38CL, LumeLEX® 2084

Special Glass Color Filters
LSI will fabricate, on special order, glass color filters in most sizes and shapes.

FS4 — Color Filter Samples
To facilitate selection of glass color filters, LSI supplies a complete set of 1 ³/₄″ X 1 ³/₄″ labeled glass and dichroic samples in a handy carrying case.

Multicolor® Filters
Unique LSI four color glass filters create rich exciting blended color effects on all objects with brilliant four color fringed shadows on background.

No.	Glass Colors Used
760	910/930/944/921
761	910/930/921/944
762	944/921/910/930
763	944/930/910/921
764	921/944/910/930

Duocolor® Filters
LSI two color glass filters blend to form one unique color that previously could only be achieved by using two separate color filters in the same fixture. Two color fringed shadows produced on background.

No.	Glass Colors Used
770	910/944
771	910/921
772	910/930
773	944/933
774	921/930
775	930/933
776	910/948

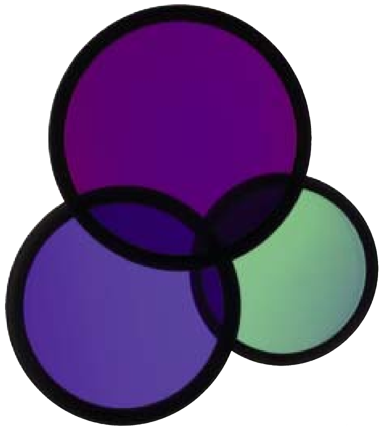
Notes:

1. Values given are approximate due to slight variations in glass color and thickness.

No.	Color	[1]% of Light Transmission
902	Medium Pink	36
903	Deep Pink	37
904	Flesh Pink	73
906	Pale Lavender	14
907	Surprise Pink	19
908	Lilac	21
910	Warm Red	10
911	Strawberry	6
912	Ruby	4
913	Magenta	1
914	Light Amethyst	25
915	Medium Amethyst	16
916	Deep Amethyst	4
917	Olive	18
918	Light Green	68
920	Medium Green	25
921	Deep Green	7
922	Silver green	65
923	Yellow Green	49
924	Emerald Green	12
925	Light Turquoise	68
926	Medium Turquoise	40
927	Deep Turquoise	17
928	Light Blue	34
930	Medium Blue	3
932	Daylight	59
933	Gene Moore Blue	18
936	Grey	56
937	Light Blue Green	17
939	Light Amber	68
940	Medium Amber	48
941	Deep Amber	43
942	Straw	78
943	Gold	87
944	Canary Yellow	84
945	Lemon	81
946	Pumpkin	32
947	Tangerine	20
948	Orange	23
949	Pink Gold	54
950	Bronze	48
951	Brass	11
952	Autumn Tan	11
953	Leaf Brown	19
954	Butter Pecan	3
955	Toasted Almond	1

COLOR MEDIA

DICHROIC COLOR FILTERS



In addition to our complete line of glass color filters, LSI now offers dichroic glass color filters that achieve purer, more saturated, richer color by selective wavelength transmission. Since these filters reflect rather than absorb the unwanted color wavelengths, a higher intensity of colored light can be obtained with fewer or lower wattage fixtures. In addition, this selective transmission allows for very accurate color matching from filter to filter.

All standard LSI filter sizes are available in a wide palette of well chosen dichroic colors that can be used with all LSI fixtures that accept accessories.

LSI dichroic glass color filters have the added benefit of being rimmed for extra durability to allow for frequent usage without fear of breakage or edge chipping.

Size	Diameter	LSI Fixture Series
AAA	2 3/8″	LumeLEX® 2020/2030/2031/2038, SSLGR16, LumeLEX MAR
AA	3″	LumeLEX® 2024 (with LX2024-Holder or LX2024-Barndoor), LumeLEX® 2026, LumeLEX® 2044, LumeLEX 2048
A	3 1/2″	LumeLEX® 2060, SSL230, SSLGR30CL, SSLGR36
C	4 3/4″	SSL238, SSLGR38CL, LumeLEX® 2084

Special Glass Color Filters
LSI will fabricate, on special order, dichroic glass color filters in most sizes and shapes not exceeding a 13″ diameter circle overall.

FS4 — Color Filter Samples
To facilitate selection of glass color filters, LSI supplies a complete set of 1 3/4″ X 1 3/4″ labeled glass and dichroic samples in a handy carrying case.

Technical Data

Dichroic color filters are created in a vacuum chamber by multi-layer vapor deposits of different minerals onto low expansion, chemically resistant Borosilicate glass.

Deposits are made in alternating layers of varying microscopic thickness which allow very narrow color wavelengths to be selectively transmitted and all other wavelengths to be reflected.

LSI does not recommend using dichroic color filters with lamps or fixtures that have beam spreads greater than 40° because a secondary color aura is created by the wide angular transmitted wavelengths that are different than the desired color wavelength.

Since there is mainly transmission and reflection of the color wavelengths by the dichroic filter and very little absorption, the dichroic filter can be used with many high temperature lights that normally would not accept color filters.

No.	Color	% of Light Transmission
2001	Light Pink	69
2002	Medium Pink	43
2003	Hot Pink	11
2004	Pale Pink	55
2010	Deep Magenta	29
2011	Lavender	24
2012	Vivid Magenta	31
2013	Lavender Accent	48
2014	Lilac	37
2015	Purple Fusion	12
2020	Sky Blue	39
2021	Sea Blue	39
2022	Cyan	33
2023	Light Blue Green	30
2024	Primary Blue	24
2025	Medium Red Blue	15
2026	Deep Purple	16
2027	Peacock Blue	53
2028	Mediterranean Blue	20
2029	Boost Blue	51
2040	Light Yellow Green	64
2041	Fern Green	47
2042	Turquoise	35
2043	Primary Green	31
2044	Industrial Green	64
2050	Yellow	80
2051	Amber	71
2052	Amber Blush	38
2053	Bastard Amber	71
2054	Goldenrod	63
2055	Bright Straw	56
2060	Medium Orange	51
2061	Orange	44
2070	Flame Red	27
2071	Primary Red	25

SORAA
SIMPLY PERFECT LIGHT

PAR38 18.5W

OUTPUT RANGE: VIVID SERIES	930 - 1050 lumen
OUTPUT RANGE: BRILLIANT SERIES	1190 - 1280 lumen
BEAM ANGLE RANGE	9°, 25°, 36°, 60°
COLOR TEMPERATURE RANGE	2700K, 3000K, 4000K, 5000K
APPLICATION	Halogen replacement for indoor & outdoor applications

120V E26 DIM IR UV

POINT SOURCE OPTICS

Exceptional beam control enables unique 9° narrow spot and smooth uniform beams

Single light source, single crisp shadow

VP_3 VIVID COLOR & VP_3 NATURAL WHITE

VIVID series provides accurate color rendering across the visible spectrum from 400nm to 700nm, with CRI/95*, R9/95*, Rf/90, Rg/100

Whiteness rendering matches or exceeds that of halogen and incandescent sources at 2700K and 3000K

ENERGY EFFICIENCY & LONG LIFE

85% more energy efficient than standard halogen lamps

Typical payback of one year or less

Rated lifetime of 35,000 hours. 3 year warranty

CERTIFICATIONS

RoHS, CE, UL/CUL, FCC Title 47 Part 15B

c UL us RoHS

HIGHLY COMPATIBLE

Narrow spot compatible with Soraa SNAP System accessories

Thermally and geometrically compatible with standard fixtures and suitable for damp locations

Suitable for fully enclosed fixtures. Can be used with front glass cover

Works with trailing edge and leading edge phase cut dimmers (see www.soraa.com/resources)

INTENDED USE AND APPLICATIONS

Intended for use in PAR38 compatible recessed downlights, track lighting and other indoor and outdoor applications

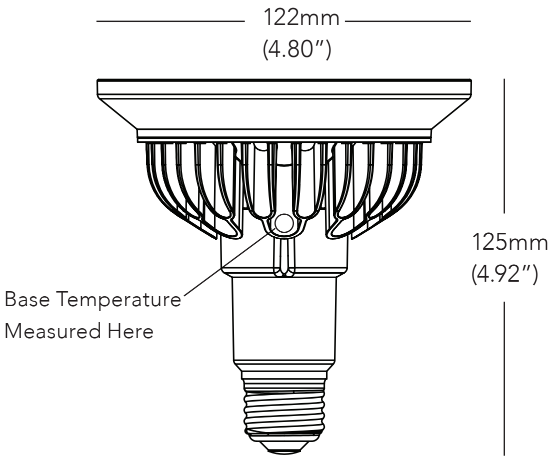
Soraa lamps are designed to safely turn down in any thermal environment not conducive to minimum airflow or proper ventilation

GENERAL SPECIFICATIONS

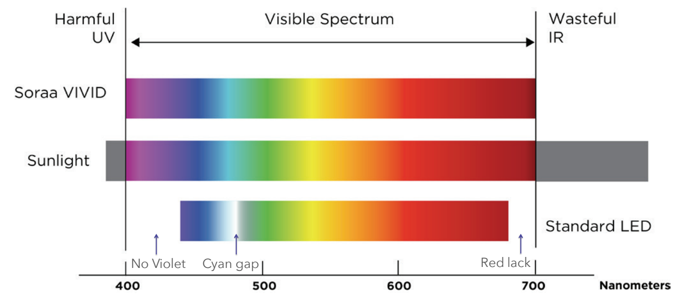
Form Factor	Operating Temperature	Electrical	Dimming and Flicker
Width: 122mm (4.80")	Minimum: -40°C (ambient)	Wattage: 18.5W	Dimmable to <10%
Height: 125mm (4.92")	Typical: 70°C - 80°C (base)	Power factor: 0.95	Flicker Index: <0.1
Weight: 305g	Maximum: 90°C (base)	Voltage: 120V +/- 12V	Percent Flicker: 31%
		Frequency: 50/60Hz	

*Metrics apply to 2700K, 3000K, 4000K. 5000K color metrics are CRI/90, R9/95

DIMENSIONS

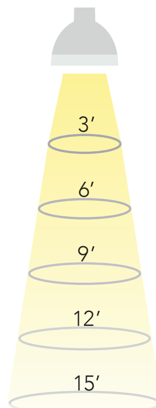


COLOR RENDERING



9 DEGREE BEAM

Beam Dia at 50% CBCP (ft)	Field Dia at 10% CBCP (ft)	Foot-candles (% of CBCP)
0.5	0.8	8.6%
0.9	1.7	2.5%
1.4	2.5	1.2%
1.9	3.4	0.7%
2.4	4.2	0.4%

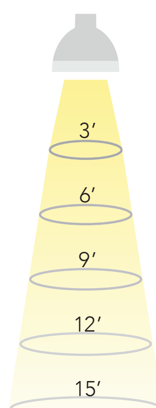


25 DEGREE BEAM

Beam Dia at 50% CBCP (ft)	Field Dia at 10% CBCP (ft)	Foot-candles (% of CBCP)
1.3	2.2	8.6%
2.7	4.4	2.5%
4.0	6.6	1.2%
5.3	8.7	0.7%
6.7	10.9	0.4%

36 DEGREE BEAM

Beam Dia at 50% CBCP (ft)	Field Dia at 10% CBCP (ft)	Foot-candles (% of CBCP)
1.9	3.5	8.6%
3.9	6.9	2.5%
5.8	10.4	1.2%
7.8	13.9	0.7%
9.7	17.3	0.4%



60 DEGREE BEAM

Beam Dia at 50% CBCP (ft)	Field Dia at 10% CBCP (ft)	Foot-candles (% of CBCP)
3.5	6.0	8.6%
6.9	12.0	2.5%
10.4	18.0	1.2%
13.9	24.0	0.7%
17.3	30.0	0.4%

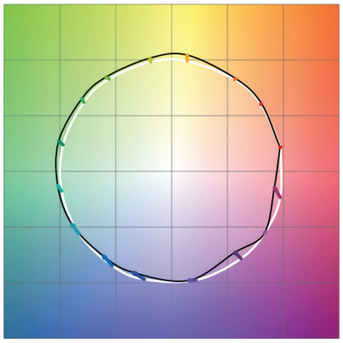
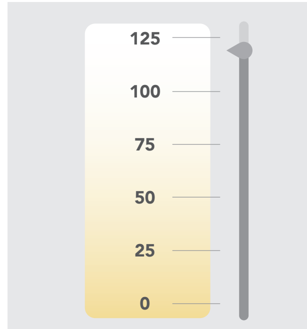
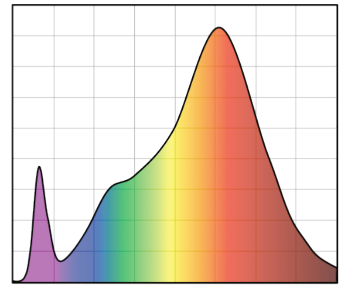
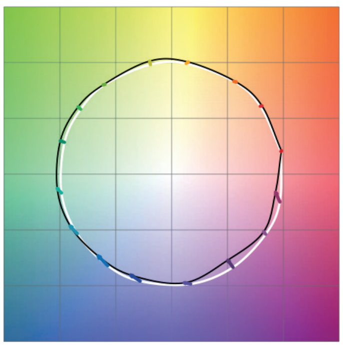
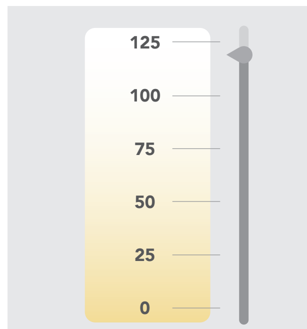
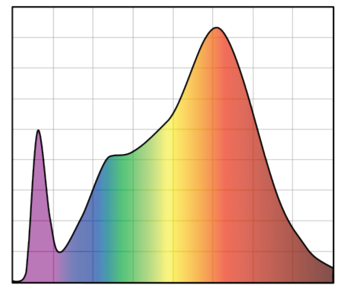
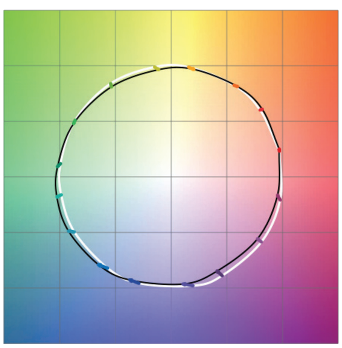
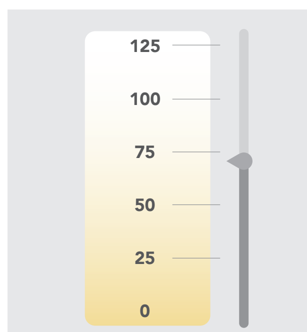
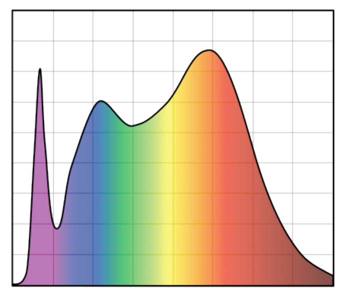
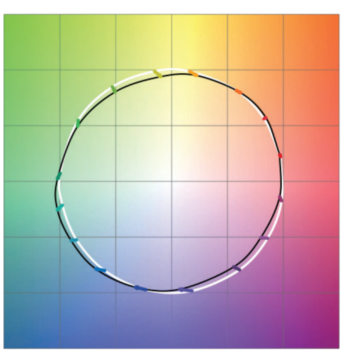
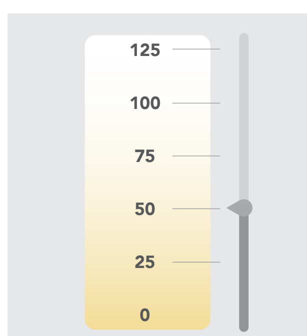
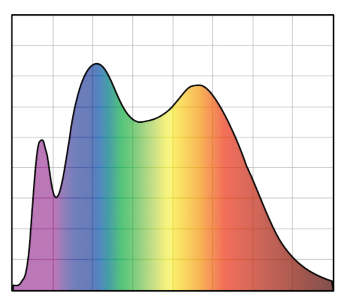
Note: Footcandles may be calculated by multiplying the CBCP of the desired model number by the percentage in the tables above

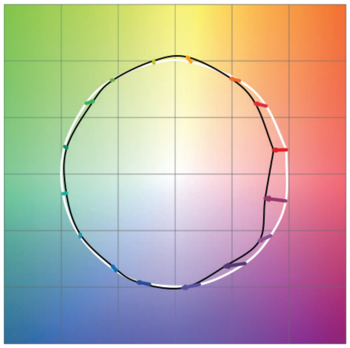
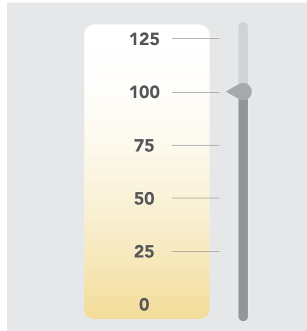
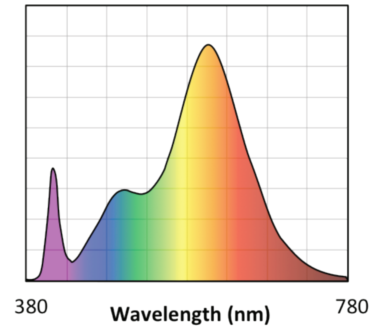
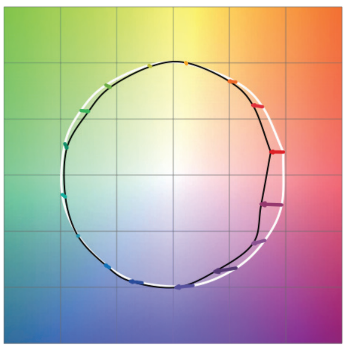
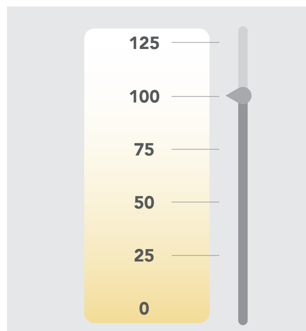
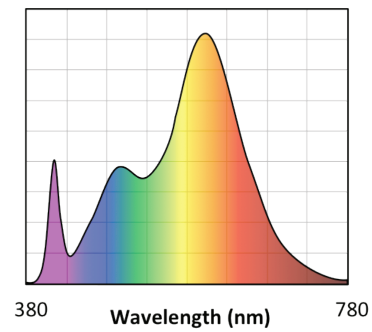
SPECIFICATIONS BY MODEL NUMBER* SORAA LED PAR38 18.5W

Model #	Product Code	CCT (K)	Beam Angle	Field Angle	CBCP (Cd)	Halogen Equivalent	Total Flux (Lm)	Efficacy (Lm/W)	McA	Energy Star	SNAP
VIVID SERIES											
SP38-18-09D-927-03	00977	2700	9	16	17200	100	930	50	3	-	YES
SP38-18-25D-927-03	00979	2700	25	40	5020	100	930	50	3	-	-
SP38-18-36D-927-03	00981	2700	36	60	2320	100	930	50	3	-	-
SP38-18-60D-927-03	00983	2700	60	90	1020	100	930	50	3	-	-
SP38-18-09D-930-03	00993	3000	9	16	18500	100	1000	54	3	-	YES
SP38-18-25D-930-03	00995	3000	25	40	5400	100	1000	54	3	-	-
SP38-18-36D-930-03	00997	3000	36	60	2500	100	1000	54	3	-	-
SP38-18-60D-930-03	00999	3000	60	90	1100	100	1000	54	3	-	-
SP38-18-09D-940-03	01009	4000	9	16	19240	100	1040	56	4	-	YES
SP38-18-25D-940-03	01011	4000	25	40	5600	100	1040	56	4	-	-
SP38-18-36D-940-03	01013	4000	36	60	2600	100	1040	56	4	-	-
SP38-18-60D-940-03	01015	4000	60	90	1140	100	1040	56	4	-	-
SP38-18-09D-950-03	01017	5000	9	16	19420	100	1050	57	5	-	YES
SP38-18-25D-950-03	01019	5000	25	40	5660	100	1050	57	5	-	-
SP38-18-36D-950-03	01021	5000	36	60	2620	100	1050	57	5	-	-
SP38-18-60D-950-03	01023	5000	60	90	1140	100	1050	57	5	-	-
BRILLIANT SERIES											
SP38-18-09D-827-03	00985	2700	9	16	22000	120	1190	64	3	-	YES
SP38-18-25D-827-03	00987	2700	25	40	6420	120	1190	64	3	-	-
SP38-18-36D-827-03	00989	2700	36	60	2960	120	1190	64	3	-	-
SP38-18-60D-827-03	00991	2700	60	90	1300	120	1190	64	3	-	-
SP38-18-09D-830-03	01001	3000	9	16	23680	120	1280	69	3	-	YES
SP38-18-25D-830-03	01003	3000	25	40	6900	120	1280	69	3	-	-
SP38-18-36D-830-03	01005	3000	36	60	3200	120	1280	69	3	-	-
SP38-18-60D-830-03	01007	3000	60	90	1400	120	1280	69	3	-	-

CCT: Correlated Color Temperature **McA**: White Point Accuracy in McA step **SNAP:** SORAA SNAP System Compatible

*Specifications are at stable warm operating conditions (25°C ambient)

SERIES/CCT	COLOR ACCURACY	WHITENESS INDEX	SPECTRAL POWER DISTRIBUTION
VIVID 2700K	 Rf: 90, Rg: 100, Rfh1: 95	 Rw: 120	 CRI: 95, R9: 95
VIVID 3000K	 Rf: 90, Rg: 100, Rfh1: 95	 Rw: 120	 CRI: 95, R9: 95
VIVID 4000K	 Rf: 90, Rg: 100, Rfh1: 95	 Rw: 70	 CRI: 92, R9: 95
VIVID 5000K	 Rf: 90, Rg: 100, Rfh1: 95	 Rw: 50	 CRI: 90, R9: 95

SERIES/CCT	COLOR ACCURACY	WHITENESS INDEX	SPECTRAL POWER DISTRIBUTION
BRILLIANT 2700K	 **Rf: 85, Rg: 92, Rfh1: 77**	 **Rw: 100**	 **CRI: 85, R9: >0**
BRILLIANT 3000K	 **Rf: 85, Rg: 92, Rfh1: 77**	 **Rw: 100**	 **CRI: 85, R9: >0**

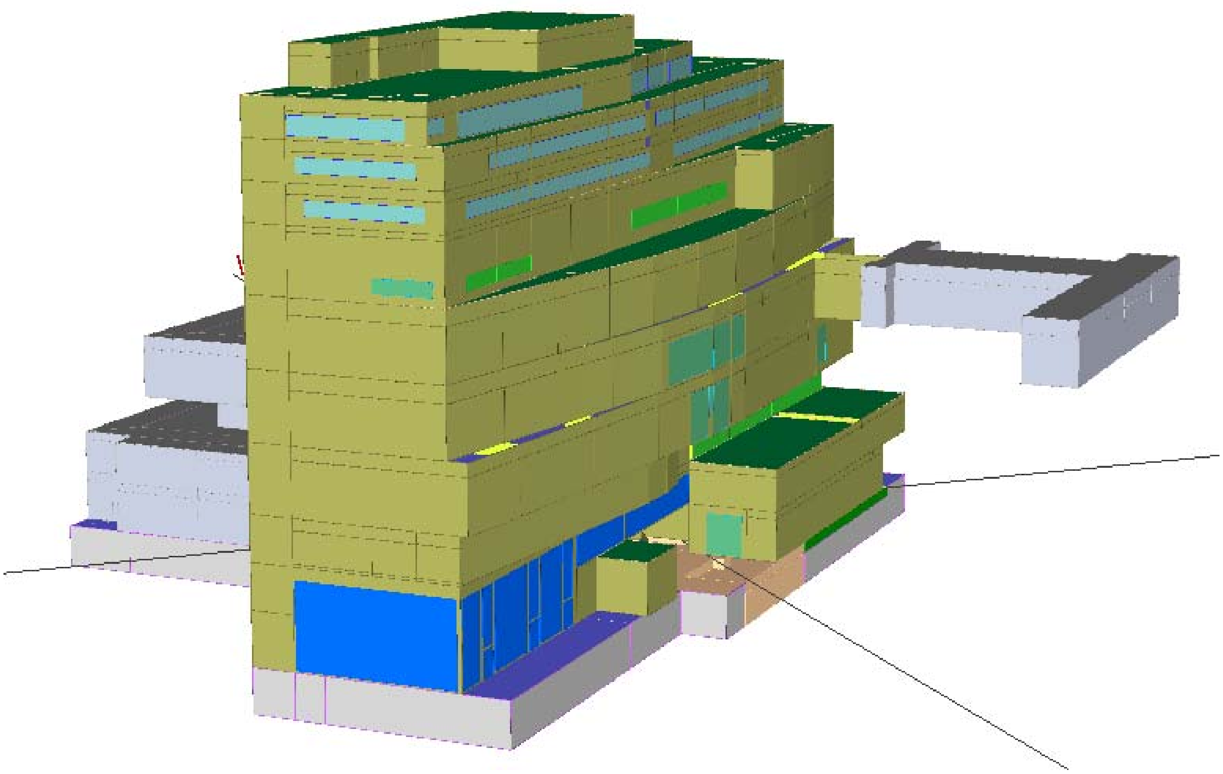
Rf: TM-30 metric measuring color fidelity (whether colors are similar to those under natural light). Rf is a more accurate version of the CRI Ra. Rf is 100 for natural light.
Rg: TM-30 metric measuring color gamut (whether colors are more saturated than under natural light). Rg is 100 for natural light.
Rfh1: TM-30 metric measuring color fidelity for red tones. Rfh1 is a more accurate version of the CRI R9. Rfh1 is 100 for natural light.
Rw: Soraa-developed metric to measure white fidelity. Rw measures the magnitude of excitation of whitening agents within whites. Rw is about 100 for natural light.

Appendix C

Final LEED Energy Analysis

San Francisco Museum of Modern Art Expansion

July 17, 2014



atelier ten

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Table of Contents

Executive Summary

Atelier Ten has prepared this LEED energy analysis to estimate the energy performance of the addition to San Francisco Museum of Modern Art (SFMOMA) located in San Francisco, CA. The purpose of this analysis is to:

- Benchmark the energy performance of the Proposed Design against a minimally compliant ASHRAE 90.1-2007 Appendix G baseline building (Baseline Case) to assess compliance with Energy and Atmosphere Pre-requisite 2 (EAp2) and estimate the number of points eligible for USGBC's LEED-NC 2009 Energy and Atmosphere Credit 1 (EAc1).

Based on the design at 100% CA and using current assumptions the Proposed Building performs 32% better in annual energy cost and 43% in annual energy consumption compared to an ASHRAE 90.1-2007 Appendix G minimally compliant baseline case. This analysis is based on an energy modeling methodology established by GBCI for this project. The energy model of the building includes both the existing and the new expansion portions of the building, however the LEED boundary and results calculation are limited to the expansion portion of the building only. The methodology is summarized in Appendix H of this report.

The results of this analysis are summarized in Table 1 below. The following energy efficiency measures (EEMs) are incorporated in the design that have helped in achieving energy savings for the project:

Envelope

- Low window to wall ratio
- High performance glazing units with low-e coating and air fill

Lighting and controls

- Daylight dimming and occupancy sensors for administrative spaces
- High efficiency LED lighting design for galleries with low overall lighting power densities
- Space by space track limiters for gallery lighting

HVAC

- Variable supply and exhaust flow for all air handling units
- Direct evaporative cooling for humidification and cooling
- Air side economizer for free cooling
- Demand controlled ventilation for gallery and back of house support spaces
- High efficiency water source heat pumps for server and IT rooms
- High efficiency condensing boilers
- High efficiency scroll chiller
- Variable flow chilled water and hot water system
- Premium efficiency fans and motors

	ASHRAE 90.1-2007 compliant Baseline Building	Proposed Design
Annual energy use	18,369 MBtu	10,470 MBtu
Annual energy cost	$512,241	$350,646
Energy Intensity	71 kBtu/sf/yr	41 kBtu/sf/yr
Annual site energy consumption savings compared to Baseline Building	N/A	43%
Annual energy cost savings compared to Baseline Building	N/A	32%
Estimated LEED EAc1 points	N/A	11

Table 1: SFMOMA Addition building energy use and LEED points

The results indicate that the relative energy and cost savings for the SF MoMA Expansion compared to ASHRAE 90.1-2007 baseline case have improved significantly since Design Development. The increase in savings is a combined result of several lighting and HVAC measures included in the 100% CD package.

Atelier Ten has also documented two exceptional calculations for the SF MoMA Expansion project. Credit from these calculations is subject to GBCI's review and approval. If both exceptional calculations are approved by GBCI, the Proposed Building is on track to achieve 35% savings in terms of annual energy cost and 47% in terms of annual energy consumption compared to an ASHRAE 90.1-2007 minimally compliant baseline case. The Proposed Design with execptional calculations is anticipated to achieve 12 points under LEED EA Credit 1 for Optimize Energy Performance.

Detailed assumptions for the analysis including occupancy and internal loads, envelope construction, typical use schedules, and HVAC parameters, are presented at the end of this report.

Introduction

The SFMOMA Expansion will add approximately 280,000 square feet of conditioned space to the existing Botta building, including approximately 130,000 square feet of gallery space. The program consists of art galleries, meeting and conference rooms, gallery support and storage spaces, library and five levels of administrative areas. For this analysis, Atelier Ten benchmarked the Proposed Building with the minimum requirements of ASHRAE 90.1-2007 Appendix-G and estimated the number of LEED EA credit 1 points and compliance with EA prerequisite 2. The update to the energy model is based on the 100% CD documentation package issued July 31, 2013, subsequent addendums, email and phone correspondence with the design team.

Atelier Ten created several whole building energy models using eQUEST v3.64 (DOE-2.2 software). These energy models compare the relative energy use throughout the year and identify specific energy demands for heating, cooling, pumps, fans, lighting, equipment, and domestic hot water. The first model, called the Baseline Case, represents a minimally compliant ASHRAE 90.1-2007 building. The Proposed Design represents SF MoMA Expansion's performance without exceptional calculation measures incorporated.

Atelier Ten has also documented the two exceptional calculations for this project. These calculations are performed separately from the simulation software due to the software limitations described in the subsequent sections of the report. Credit from these calculations is subject to GBCI's review and approval.

The following list shows major updates incorporated in this CA energy model since the last model update in CD phase.

Envelope

- Exterior wall
- Fenestration type and size

Lighting

- Ambient and decorative lighting power densities
- Exterior lighting power

HVAC

- Water source heat pumps for server / IT rooms.
- Cooling tower efficiency and characteristics of the chilled, heating and condenser water systems
- HVAC system type serving spaces with conditioning criteria A (applies to Baseline Building only).

Energy models are representations of the designed building and its future operations. Energy modeling is a design optimization tool which predicts the energy performance of a building. The results from the energy model are accurate in terms of comparative evaluations of energy optimization measures assuming that all the other assumptions remain consistent. However, because energy model results rely on many assumptions about building occupancy patterns, they should not be construed as an absolute prediction of future building energy use.

Summary of Results

The SFMOMA Expansion is an internal load dominated building as a result of occupant, ambient and decorative lighting loads. The results indicate that the lighting and conditioning energy are the largest energy consuming end-uses in the building. The conditioning energy use is derived from the need to control temperature and humidity within the Class A spaces and high-quality lighting is required to display the art. The results of the analysis indicate that the Proposed Building consumes 43% less energy on an annual basis compared to as minimally compliant ASHRAE 90.1-2007 building. Further, these saving translate to 32% in terms of annual utility cost. The graph below summarizes the annual end use distribution of the Proposed as well as the Baseline Building.

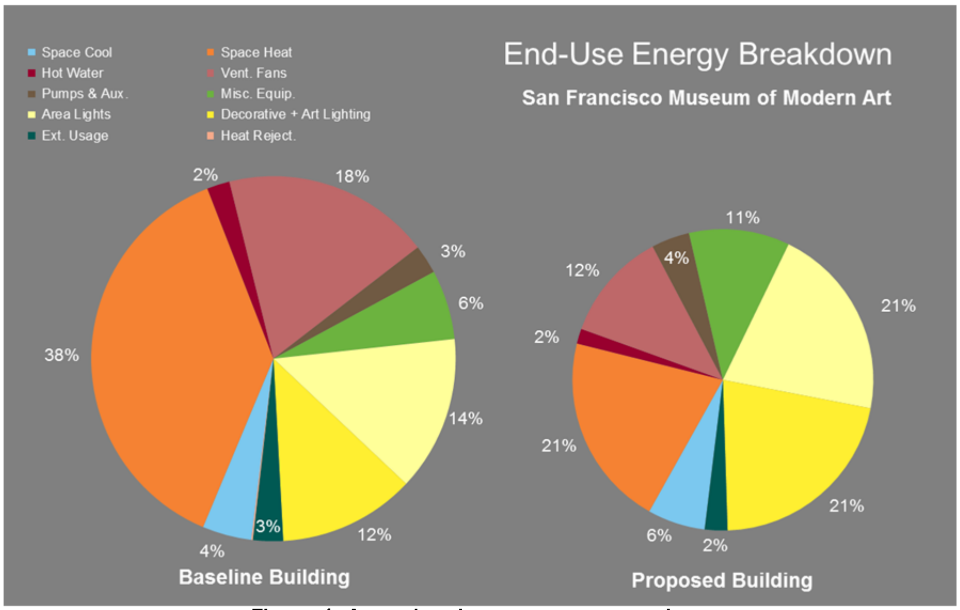

Figure 1: Annual end-use energy comparison

Annual Energy Consumption

The annual energy consumption described in this report is the energy performance of the extension building within the LEED boundary. It does not include the energy use of the existing Botta building. Site energy consumption also does not the include fuel consumption or cost related to transmission and source-to-site losses. The results indicate that the Proposed Building shows a reduction in annual energy consumption by approximately 43% over the minimally code-compliant ASHRAE 90.1-2007 Appendix-G building. The annual energy consumption is shown in Figure 2 below and is broken out into the building end uses. The results are shown in both total annual energy consumption (in million Btus) and in annual site energy intensity (kBtu/ft^2/yr).

- Space heating, lighting energy and ventilation fans are the most significant energy end uses in the Proposed Building. The HVAC scheme allows the Proposed Building to reduce the overall HVAC energy use by approximately 50%. The variable air volume conditioning of the gallery and conservation spaces with strict conditioning criteria is the single largest energy saving measure included in the Proposed Building. Further, the analysis demonstrates that reheat and humidification energy is greatly reduced in the Proposed Building due to the configuration of a dual duct dual fan system with direct evaporative cooling for humidification.
- Cooling energy is a relatively small component of the overall energy use because the temperature of the outside air is cool and dry enough for majority of the year to provide free cooling with the air side economizer and also allow direct evaporative cooling to be effective.
- Ambient lighting energy is reduced by approximately 20% as compared to the Baseline Building due to the use of highe efficiency lighting fixtures. Further lighting controls such as daylight dimming and occupancy sensors assist in reducing the overall lighting energy use.
- While the results of this analysis show that the facade plays a limited role in the overall annual energy consumption, several areas of the façade and roof do have high performance envelope design, including double

glazing and insulated walls and roof. These envelope improvements decrease the heat gains and losses through the envelope and minimize peak heating and cooling loads in the spaces. The performance of the facade also improves thermal and visual comfort (heat gain and glare) in perimeter spaces.

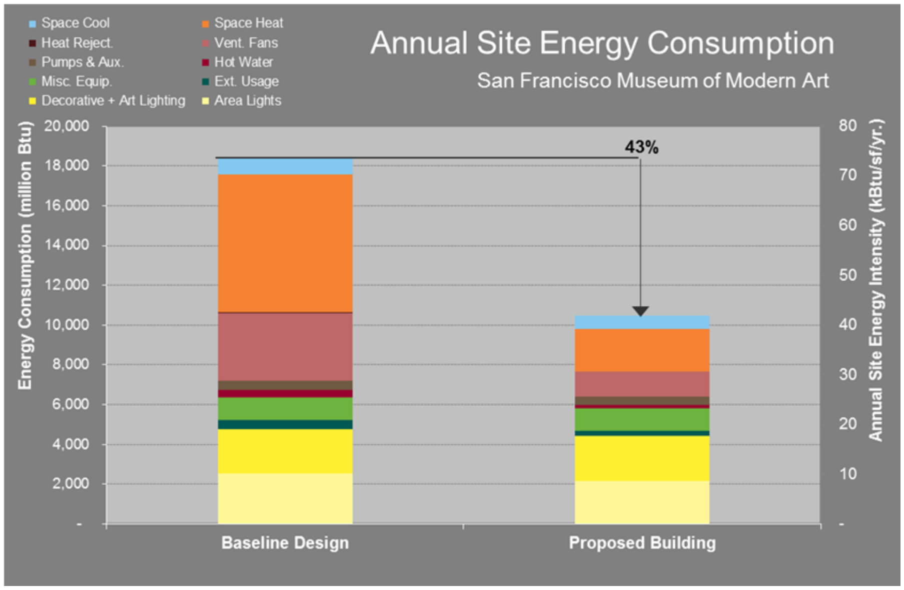

Figure 2: Annual site energy consumption comparison

Annual Energy Cost

The Proposed Building demostrates a reduction in annual energy cost by approximately 32% over the minimally code-compliant ASHRAE 90.1-2007 Appendix-G building. These savings are significantly greater than the 10% minimum energy cost savings requirement for Energy and Atmosphere Prerequisite 2. These results are shown in Figure 3 below in both energy cost (left y-axis) and energy cost per unit area (right y-axis). As shown in the graph, the Proposed Building reduces space heating (natural gas cost savings), ventilation fan and lighting energy consumption (electricity cost savings) which is primarily a result of an efficient HVAC and lighting system.

The Proposed Building is currently on-track to exceed the San Francisco Green Building Ordinance minimum requirement of 15% annual energy cost reduction. Based on current performance the project is expected to meet the mandatory LEED EA prerequisite 2 for minimum energy performance and is anticipated to achieve 11 points under LEED EA Credit 1 for Optimize Energy Performance.

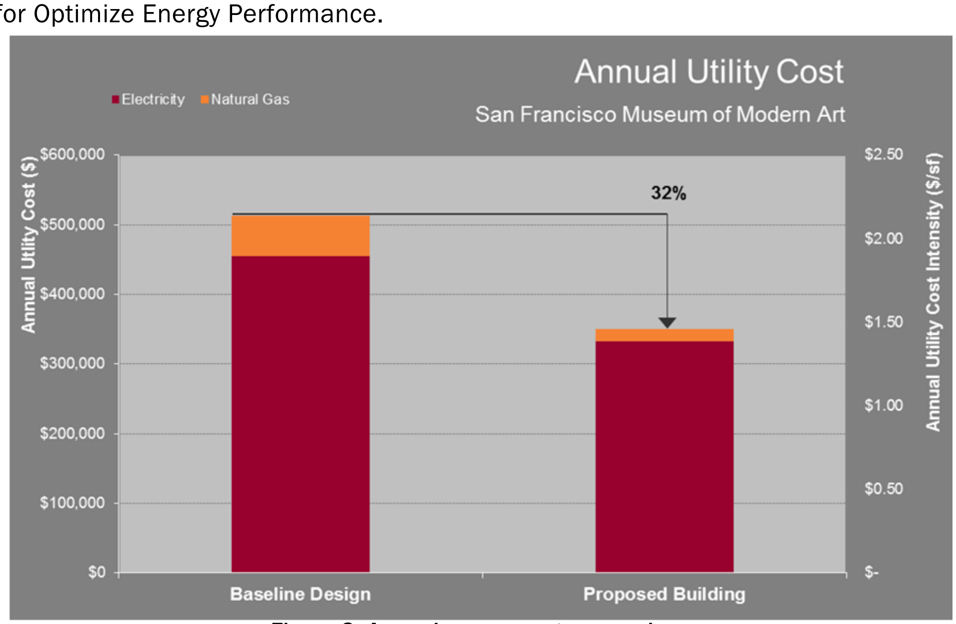

Figure 3: Annual energy cost comparison

Critical Interpretations

The SF MoMA expansion includes a complex HVAC system and a physical connection to an existing building. There are therefore several issues where thr energy modeling methodology is open to interpretation. The following narrative explains critical interpretations of ASHRAE 90.1-2007 Appendix G Standard & USGBC's LEED Interpretations that have been used in this analysis.

LEED Modeling Methodology

The project is applying for LEED 2009 New Construction certification for the new addition. However, the energy model is informed by the methodology applied in the LEED Commercial Interiors rating system, because the HVAC systems for the existing and the new building are not independent.

The energy model applies a modeling methodology outlined by GBCI (see Appendix H). This is based upon an approach described in the 2009 Edition LEED Commercial Interiors Reference Guide and the Advanced Energy Modeling for LEED Manual modeling guidance, which considers the energy use of spaces within the LEED project boundary when they are served by HVAC systems that also serve spaces outside of the LEED project boundary. The approach requires modeling the existing and new buildings and metering each end-use so that the new addition's energy use can be isolated. Supplemental information for modeling this approach has been provided by GBCI and applied such that the Commercial Interiors methodology is extended to LEED for New Construction. The total energy use of the SFMOMA addition is calculated according to conditioned areas within the LEED project boundary so that the savings reported refer only to the new addition and not the whole building.

This approach was reviewed and approved with Gail Hampsmire of GBCI on June 11, 2012 and approved for SF MoMA Expansion project.

LEED Interpretation for Baseline Case HVAC System

ASHRAE 90.1-2007 Appendix G does not fully address the conditioning criteria typically applied to fine art museums. LEED Interpretation #10047 shown below, allows use of an HVAC system described in ASHRAE HVAC Application 2007 Handbook.

ID#10047 MADE ON 05/09/2011

PREREQUISITE/CREDIT: EAP2 - MINIMUM ENERGY PERFORMANCE
RATING SYSTEM: LEED BD+C: NEW CONSTRUCTION, LEED BD+C: CORE AND SHELL, LEED BD+C: SCHOOLS

Inquiry

For a fine art museum pursuing EAp2, is it acceptable to use the systems and recommendations described in the ASHRAE HVAC Applications 2007 Handbook as the baseline in cases where Appendix G does not adequately describe a typical preservation area?

Ruling

The outlined approach is acceptable. Applicable internationally.

Internationally applicable

ASHRAE HVAC Applications 2007 Handbook (page 21.16 and beyond) describe a Constant Air Volume system as a primary HVAC system that provides a good preservation environment for a museum. Based on the recommendations described in the ASHRAE HVAC Applications 2007 Handbook, the Baseline Building for SF MoMA Expansion is modeled with a constant air volume ventilation system for the preservation and gallery areas with strict conditioning criteria.

Exceptional Calculations

The following exceptional calculations have been documented for this project. These calculations are performed separately from the simulation software due to the software limitations described below. Credit from these calculations is subject to GBCI's review and approval. The savings from these measures are not included in Table 1 summary above and are included in the "Exceptional Calculations" section of this report.

- Direct Evaporative Humidification – A Direct Evaporative Humidification (DEH) device, which cools and humidifies mixed air through the evaporation of water, is included as part of the mechanical system. Since the simulation software is unable to model this type of device in the fashion it is designed, the building's annual cooling and humidification consumption savings were determined by applying an exceptional calculation. The calculation methodology is included in the "Exceptional Calculations" section of this report.

- Current Limiters for Track Lighting in Galleries - Track lighting designed for galleries is categorized as decorative / art lighting and documented as "process" load according to the ASHRAE 90.1-2007 Appendix G modelling protocol. Track lighting in the gallery space of the Proposed Building is designed with current limiting devices. These devices are permanently installed between the primary circuit and the track to limit the total wattage that can be handled by a panel at any given time. This decorative / art lighting energy reducing strategy is documented as an exceptional calculation as per the USGBC modeling protocol. The calculation methodology is included in the "Exceptional Calculations" section of this report.

With both exceptional calculations, the Proposed Building performs 35% better in annual energy cost and 47% in annual energy consumption compared to an ASHRAE 90.1-2007 minimally compliant baseline case. The Proposed Design with execptional calculations is anticipated to achieve 12 points under LEED EA Credit 1 for Optimize Energy Performance.

Exceptional Calculations

Atelier Ten has documented the two exceptional calculations for this project. These calculations are performed separately from the simulation software due to the software limitations described below. Credit from these calculations is subject to GBCI's review and approval. If approved, additional energy cost savings and LEED EAc1 points will be earned above and beyond those explained in the Summary of Results chapter of this report.

Direct Evaporative Humidification

A Direct Evaporative Humidification (DEH) device will be included as part of the mechanical system. This device cools air through evaporation of water and is hence suitable for application in low-humidity climates. The process of direct evaporation also humidifies the mixed and/or outside air. For this analysis, the DEH provides cooling and humidification when the enthalpy of outside air / mixed air is equal to or higher than the enthalpy of the air leaving the central cooling coil (leaving dry bulb temperature of 52.2°F) and the humidity ratio is less than 0.008 lb of water / lb of dry air. The DEH will also provide humidifaction when the humidity ratio is less than 0.008 lb of water / lb of dry air. Since the simulation software is unable to model this device in the fashion it is controlled, the building's annual cooling and humidification consumption savings were determined by applying the following calculation methodology to all hours of the year:

- The mixed air enthalpy or "energy" content of the air, which includes both the sensible and the latent components, are determined from the psychrometric chart using the dry bulb temperature and humidity ratio of the air just before entering the cooling coil. The sensible component corresponds to the dry bulb air temperature while the latent component is associated with the wet bulb temperature and humidity level. Both the air temperature and humidity ratio entering the cooling coil are obtained from the energy model hourly outputs.

- The mixed air enthalpy value is used to determine whether DEH can meet part of the cooling load for each hour. DEH will always provide humidification. Three enthalpy regions corresponding to these criteria were identified based on the mechanical narrative and discussions with the design team. Refer to Table 2 for the criteria of A, B, and C regions.

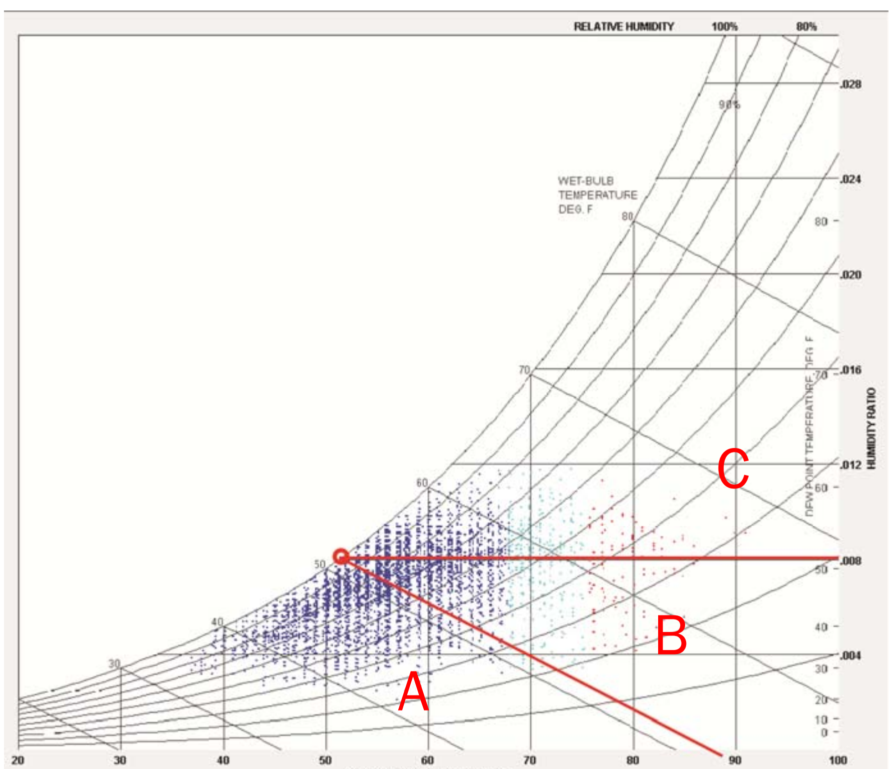

Figure 4: Mixed Air Region Classification for DEH Potential*

* This chart is included to show the regions of DEH potential. The chart graphs outside air conditions, not mixed air.

Criteria	Region	DEH Potential
Specific enthalpy less than 21.3 Btu/lb (comparable to wet bulb temperature less than 52.2°F)	A	DEH provides humidification.
Dew point less than 54.2°F and specific enthalpy greater than 21.3 Btu/lb (comparable to wet bulb temperature greater than 52.2°F)	B	DEH can partially meet cooling load and fully meet humidification load. Some cooling also required by cooling coil.
Dew point greater than 54.2°F or	C	DEH is OFF. No humidification or cooling provided by DEH. Cooling and dehumidification will be supplied by cooling coil as necessary.

Table 2: SFMOMA Addition - Mixed Air Region Classification for DEH Potential

Using the mixed air enthalpy value and dew point, each hour is assigned to one of these regions.

1. To determine the cooling coil energy consumption, the following equation is used:

   Cooling energy (Btu/hr) = Density of air (lb/ft^3) * Airflow rate (ft^3/hr) * Change in specific enthalpy (Btu/lb)
   where,
   density of air is assumed to be 0.075 lb/ft^3,
   airflow rate for each hour is obtained from the energy model hourly outputs and
   change in specific enthalpy is the difference between the mixed air enthalpy and the 21.3 Btu/lb for region B.

   All other cooling and humidification is provided by the DEH in Region B. All humidifcation is provided by the DEH in Region A. No cooling or humidification savings from the DEH will be seen in Region C.

2. Summing the cooling energy for Regions A, B and C yields the annual cooling consumption with the DEH accounted for. All humidification is provided by the DEH in Regions A and B. There is no humidification in Region C

This calculation procedure is used to estimate the savings for humidification and cooling on an hourly basis. Average annual efficiencies of the heating and cooling equipment are applied to convert the annual cooling and heating load to annual cooling and heating energy consumption.

Track Lighting Current Limiters for Galleries

The lighting power for each gallery is divided into ambient lighting and decorative / art lighting. All track lighting that is designed for galleries is categorized as decorative / art lighting, and documented as "process" load according to the ASHRAE 90.1-2007 Appendix G modeling protocol. However, track lighting in the gallery space of the Proposed Building is designed with current limiting devices. These devices are permanently installed between the primary circuit and the track to limit the total wattage that can be controlled by a panel at any given time. The calculation in Table 3 shows the estimated Lighting Power Density (LPD) reduction for track lighting in gallery spaces. The LPDs under "Maximum Lighting Power" are used consistently in the Baseline and Proposed Building energy model.

5341 - SF MoMA Process Lighting Power Density Calculations Galleries								
				Lighting Power with Current Limiting Strategy		Maximum Lighting Power		
Floor	Panel No.	Space	Area (sf)	Total Panels Watts	LPD (W/sf)	Total Panel Watts	LPD (W/sf)	Panel Name & Dwg No.
3	1N	Calder Gallery						
2	1N	Seminar						
2	1N	Seminar						
2	1N	Multipurpose Room	7,874	8,500	1.08	9,400	1.19	Panel LCP-1NT / E021
1	2S	Howard Street, Lobby, Ticket Lobby,						
1	2S	Retail	18,485	25,000	1.35	27,700	1.50	Panel LCP-2ST/E022
3	3S	Art Court, Interpretation Gallery						
3	3S	Photo Special Exhibition	12,820	17,000	1.33	18,900	1.47	Panel LCP-3ST/E023
4	4N	White Box						
4	4N	Bridge & Under Bridge Gallery	4,700	12,700	2.70	14,100	3.00	Panel LCP-4NT/E024
4	4S	Fisher Gallery (Sculpted Ceiling)						
4	4S	City Gallery Stair						
4	4S	Elevator Lobby	16,250	31,600	1.94	35,100	2.16	Panel LCP-4ST/E024
5	5S	Fisher Gallery (Sculpted Ceiling)						
5	5S	City Gallery						
5	5S	Elevator Lobby	21,210	32,500	1.53	36,100	1.70	Panel LCP-5ST/E025
6	6N	Architecture & Design	3,170	6,600	2.08	7,300	2.30	Panel LCP-6NT/E026
6	6S	Fisher Gallery (Flat Ceiling)						
6	6S	City Gallery						
6	6S	Elevator Lobby	17,990	38,900	2.16	43,200	2.40	Panel LCP-6ST/E026
7	7N	Media Arts	2,770	5,000	1.81	5,500	1.99	Panel LCP-7NT/E027
7	7S	Contemporary Painting & Sculpture						
7	7S	Media Arts Collection						
7	7S	Elevator Lobby	12,080	25,000	2.07	27,800	2.30	Panel LCP-7ST/E027

Table 3: SFMOMA Addition - Current Limiters for Track Lighting in Galleries

Cumulative Case

Reduced lighting power density in the individual exceptional calculations as compared to the Baseline Building affect internal gains, lowers space cooling and therby also affects the performance of the DEH system. The effect of both the exceptional calculations are therefore analysed together to estimate the annual cost savings over a minimally compliant Baseline Building. The following graphs present the estimated annual energy and utility cost savings with both exceptional calculations combined together. The Proposed Design with Exceptional Calcs includes LPDs from the “Current Limiting Strategy” for process lighting. DEH savings are then calculated for the Proposed Building on an annual basis and compared to the Baseline Building. The results of the analysis indicate that the Proposed Building with Exceptional Calculations consumes 47% less energy on an annual basis compared to as minimally compliant ASHRAE 90.1-2007 building. Further, these saving translate to 35% in terms of annual utility cost. Based on current performance the project is anticipated to achieve 12 points under LEED EA credit 1 for Optimize Energy Performance.

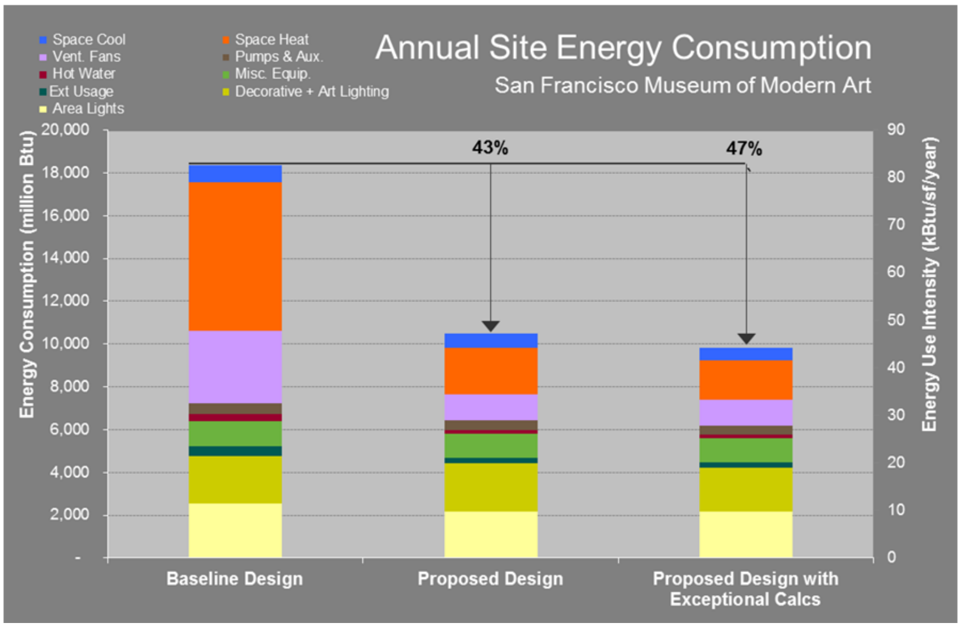

Figure 5: Annual site energy comparison

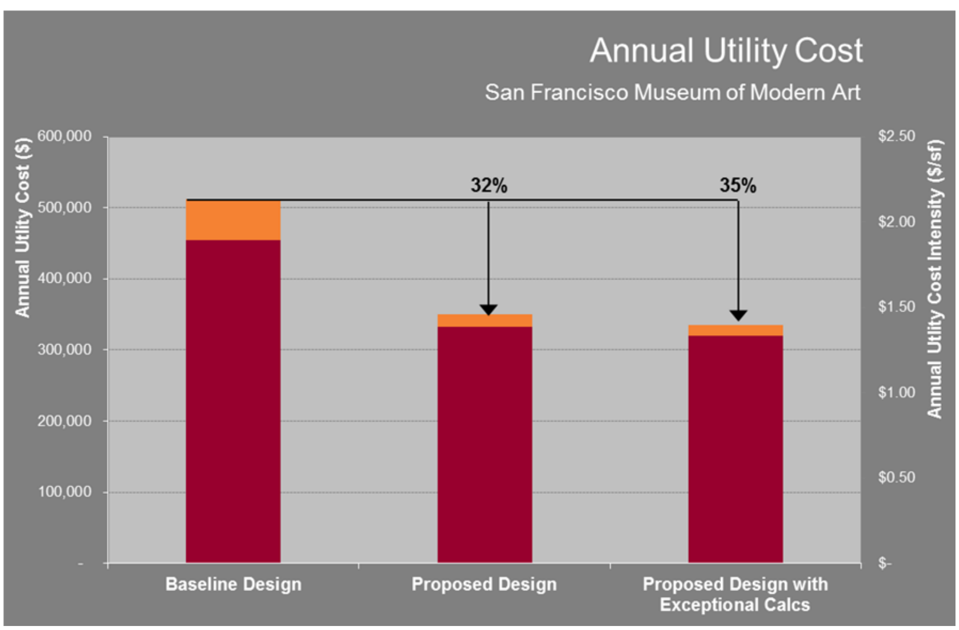

Figure 6: Annual energy cost comparison

Appendices

The assumptions included in the Appendices and in Section 1.4 tables (uploaded to LEED Online) are applicable to exisiting and new expansion of SFMOMA. The final results are however calculated for the new expansion portion (LEED boundary) only by using the methodology suggested by GBCI. This methodology is summarized in Appendix H of this report.

Appendix A: General Information

Analysis Tool: eQUEST (DOE 2.2 Engine) v3.64
Weather File: DOE 2.2 TMY2 weather file for San Francisco, California
ASHRAE Climate Zone: 3C
Energy Code used: ASHRAE 90.1 2007 Appendix-G Performance Rating method
Ventilation Code: ASHRAE 62.1-2004
Building Area (as simulated with DOE 2.2): 279,545 gross ft² (new addition)
Number of Floors: 11 above grade, 1 below grade
Construction: 68% new construction, 32% existing building
Principal Heating Source: HW from on-site boilers
Principal Cooling Source: CHW from on-site chillers

Space Type	**Whole (Existing Botta + New Addition) building Conditioned Area (ft²)**	**New Addition Conditioned Area (ft²)**
Below Grade	68,972	30,206
First Floor	54,997	16,480
Second Floor	51,819	22,712
Third Floor	34,873	22,209
Fourth Floor	51,340	30,367
Fifth Floor	33,254	23,204
Sixth Floor	34,520	34,218
Seventh Floor	23,436	20,488
Eighth Floor	20,543	17,522
Ninth Floor	21,004	19,922
Tenth Floor	14,660	12,971
Total	414,672	250,298

Appendix B: Building Shell Construction

Building Element	Baseline Building	Proposed Building
Exterior Wall Construction	Existing building exterior wall: Total U-value: 0.266 Btu/hr-ft^2-°F Total R-value: 3.75 hr-ft^2-°F/Btu ASHRAE Compliant Zone 3C exterior wall construction: Total U-value: 0.084 Btu/hr-ft^2-°F Total R-value: 12 hr-ft^2-°F/Btu R-13.0 + R-3.8 c.i.	Existing building exterior wall: Total U-value: 0.266 Btu/hr-ft2-°F Total R-value: 3.75 hr-ft2-°F/Btu New building exterior wall with 4.5 inch fill insulation: Total U-value: 0.05 Btu/hr-ft2-°F Total R-value: 11 hr-ft2-°F/Btu
Roof Construction	Existing building roof construction: Total U-value: 0.266 Btu/hr-ft^2-°F Total R-value: 3.75 hr-ft^2-°F/Btu ASHRAE Compliant ZONE 3C exterior roof construction: Total U-value: 0.048 Btu/hr-ft^2-°F Total R-value: 20.8 hr-ft^2-°F/Btu	Existing building roof construction: Total U-value: 0.266 Btu/hr-ft^2-°F Total R-value: 3.75 hr-ft^2-°F/Btu New building roof construction: Total U-value: 0.041 Btu/hr-ft^2-°F Total R-value: 24 hr-ft^2-°F/Btu
Floor Construction	Same as proposed design	6” Concrete slab
Slab on Grade	ASHRAE Compliant Zone 3C unheated slab F-0.730	6” Concrete slab
Below Grade Walls	8” Concrete slab C-factor 1.14	8” Concrete slab with R10 continuous insulation C-factor 0.092
Window-to-Wall Ratio	14%	14%
Fenestration Type	Existing Building: Single paned clear glass window New Addition: ASHRAE Compliant Zone 3C Vertical Glazing & Skylight	Existing Building: Single paned clear glass window New Addition: Insulated glazing units

Building Element	Baseline Building	Proposed Building
Fenestration U-value & SHGC	Exisiting: Windows & skylight: 1.03 Btu/hr-ft^2-°F (cog) SHGC: 0.82 New Addition: Windows: U-value 0.65 Btu/hr-ft^2-°F (overall) SHGC 0.39 Skylight: 1.17 65 Btu/hr-ft^2-°F (overall) SHGC 0.39	Exisiting Windows & skylight : U-value: 1.03 Btu/hr-ft^2-°F (center of glass) SHGC: 0.82 New Addition Windows (Center of Glass) GL-1 VT: 71%, U-Value: 0.31, SHGC: 0.57 GL-2A VT: 71%, U-Value: 0.29, SHGC: 0.57 GL-3A(1) VT: 36%, U-Value: 0.27, SHGC: 0.24 GL-3A(2) VT: 68%, U-Value: 0.27, SHGC: 0.38 GL-3A VT: 50%, U-Value: 0.27, SHGC: 0.37 GL-3B VT: 71%, U-Value: 0.31, SHGC: 0.57 GL-3C(E) VT: 72%, U-Value: 0.30, SHGC: 0.58 GL-3C(S) VT: 72%, U-Value: 0.27, SHGC: 0.39 Skylight GL-3D) VT: 33%, U-Value: 0.27, SHGC: 0.24
Window Frame Type and Conductance	Exisiting: 1.9 Btu/hr-ft^2-°F	Exisiting: 1.9 Btu/hr-ft^2-°F New Addition: Aluminum with thermal break 1.245 Btu/hr-ft^2-°F
External Shading	none	none

Appendix C: Building occupancy, lighting power density and equipment load

The table below lists maximum occupancy, the average peak connected power density (Watts/ft²) of the ambient lighting (including task lights), decorative lighting, and the average peak equipment load (Watts/ft²) for all zones throughout the building. Savings can be demonstrated for ambient lighting, so these values are extrated below in the LPD summary. Decorative lighting and art lighting are included in equipment loads (EPD), as the baseline and proposed values must be equivalent in these cases.

Building Element	**Baseline Building**		**Proposed Building**	
	Space	**LPD (W/sf.)**	**Space**	**LPD (W/sf.)**
	New Addition			
	Gallery	1.0 (ASHRAE 90.1-2007 ambient allowance)	Gallery	See Appendix I below
	New Offices – Flr 8 to 10	1.1	New Offices – Flr 8 to 10	0.8
	White box	1.3	White box	0.81
	Classroom	1.4	Classroom	1.0
	Conference/Multipurpose	1.3	Conference/Multipurpose	0.91
Interior Lighting Power Density	Conservation	1.4	Conservation	1.0
	Corridor	0.5	Corridor	0.45
	Storage	0.8	Storage	0.72
	Art Storage	1.4	Art Storage	1.0
	Retail	1.7	Retail	1.19
	Mech Room	1.5	Mech Room	1.05
	Stairs	0.6	Stairs	0.54
	Library Stacks	1.7	Library Stacks	1.19
	Corridor	0.5	Corridor	0.45
	Restroom	0.9	Restroom	0.81
	Kitchen	1.2	Kitchen	0.85
	Workshop	1.9	Workshop	1.33

	Existing Building			
	Atrium	3.78	Atrium	3.78
	Offices	1.06	Offices	1.06
	Galleries: Gallery Floor 2 Gallery Floor 3 Gallery Floor 4	 3.09 1.3 2.11	Galleries: Gallery Floor 2 Gallery Floor 3 Gallery Floor 4	 3.09 1.3 2.11
	Wattis Theater	0.46	Wattis Theater	0.46
	Museum Store	2.51	Museum Store	2.51
	Café	2.51	Café	2.51
	Work Spaces Basement	1.24	Work Spaces Basement	1.24
	Stair	0.80	Stair	0.80
PROCESS LOADS – Decorative & Art Lighting and Receptacle Equipment Power Density	**Space**	**EPD (W/sf.)**	**Space**	**EPD (W/sf.)**
	Decorative and art lighting only			
	Galleries: Howard Street Gallery Art Court Calder Gallery Photo Special Exhibition Fisher Collection Flr 4-5 City Gallery – Flr 4-5-6 Arch+Desigh Contemporary Gallery Media Arts Fisher Destination White box	See appendix I below	Galleries: Howard Street Gallery Art Court Calder Gallery Photo Special Exhibition Fisher Collection Flr 4-5 City Gallery – Flr 4-5-6 Arch+Desigh Contemporary Gallery Media Arts Fisher Destination White box	See appendix I below
	Receptacle equipment only			
	Media Arts Galleries	9.6 kW	Media Arts Galleries	9.6 kW
	Typical Gallery	0.25	Typical Gallery	0.25
	Offices	0.75	Office	0.75
	White box	1.75	White box	1.75
	Classroom	1.25	Classroom	1.25
	Education Multipurpose-1	1.0	Education Multipurpose	1.0
	Multipurpose-2	0.3	Education Multipurpose-2	0.3
	Graphic Study/Support	1.5	Graphic Study/Support	1.5
	Meeting Room-c	2.5 kW	Meeting Room-c	2.5 kW per room
	Red Room	2.25	Red Room	2.25
	General Storage	0.75	General Storage	0.75
	Art Storage	0.75	Art Storage	0.75
	Conference	1.5	Conference	1.5

	Retail	0.5	Retail	0.5
	Mech Room	0.75	Mech Room	0.75
	Offices	1.5	Offices	1.5
	Library Stacks	0.75	Library Stacks	0.75
	Kitchen	10	Kitchen	10
	Café/Dining	0.75	Café/Dining	0.75
	Lobby	0.75	Lobby	0.25
	Workshop	0.75	Workshop	0.75
Exterior Lighting	34 kW		19 kW	
Elevators	36 kW		36 kW	

Appendix D: Building occupancy, lighting and equipment schedules

The modeling assumptions for the maximum occupancy and area per person in the building were estimated based on discussion with Facilities Management at SFMOMA. Peak lighting and equipment loads were diversified by estimating an electric usage pattern for the building based on scheduling assumptions. The tables below list occupancy, lighting and equipment schedules assumed for the individual usage type for the building. The owner and the design team should review the schedules and provide feedback based on their expected use of the building.

Maximum Occupancy for Existing and New Building Energy Model: 8,390 people (the schedules below diversity this maximum occupancy number).

Gallery Space Schedule

Hour		Occupancy			Lighting[1]			Misc. Equipment		
From	To	Open Day	Thursday	Closed/ Holiday/ Wednesday	Open Day	Thursday	Holiday/ Wednesday	Open Day	Thursday	Closed/ Holiday/ Wednesday
12:00 AM	1:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
1:00 AM	2:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
2:00 AM	3:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
3:00 AM	4:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
4:00 AM	5:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
5:00 AM	6:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
6:00 AM	7:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
7:00 AM	8:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
8:00 AM	9:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
9:00 AM	10:00 AM	10%	10%	0%	100%	100%	5%	100%	100%	5%
10:00 AM	11:00 AM	10%	10%	0%	100%	100%	5%	100%	100%	5%
11:00 AM	12:00 PM	20%	20%	0%	100%	100%	5%	100%	100%	5%
12:00 PM	1:00 PM	20%	20%	0%	100%	100%	5%	100%	100%	5%
1:00 PM	2:00 PM	20%	20%	0%	100%	100%	5%	100%	100%	5%
2:00 PM	3:00 PM	20%	20%	0%	100%	100%	5%	100%	100%	5%
3:00 PM	4:00 PM	20%	20%	0%	100%	100%	5%	100%	100%	5%
4:00 PM	5:00 PM	20%	20%	0%	100%	100%	5%	100%	100%	5%
5:00 PM	6:00 PM	50%	30%	0%	100%	100%	5%	100%	100%	5%
6:00 PM	7:00 PM	10%	50%	0%	20%	100%	5%	5%	100%	5%
7:00 PM	8:00 PM	10%	50%	0%	5%	100%	5%	5%	100%	5%
8:00 PM	9:00 PM	0%	20%	0%	5%	100%	5%	5%	100%	5%
9:00 PM	10:00 PM	0%	1%	0%	5%	20%	5%	5%	20%	5%
10:00 PM	11:00 PM	0%	0%	0%	5%	5%	5%	5%	5%	5%
11:00 PM	12:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%

High Occupancy Gallery

Hour		Occupancy			Lighting			Misc. Equipment		
From	To	Open Day	Thursday	Closed / Holiday/ Wednesday	Open Day	Thursday	Closed / Holiday/ Wednesday	Open Day	Thursday	Closed / Holiday/ Wednesday
12:00 AM	1:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
1:00 AM	2:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
2:00 AM	3:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%

3:00 AM	4:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
4:00 AM	5:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
5:00 AM	6:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
6:00 AM	7:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
7:00 AM	8:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
8:00 AM	9:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
9:00 AM	10:00 AM	1%	1%	0%	100%	100%	5%	100%	100%	5%
10:00 AM	11:00 AM	30%	30%	0%	100%	100%	5%	100%	100%	5%
11:00 AM	12:00 PM	40%	40%	0%	100%	100%	5%	100%	100%	5%
12:00 PM	1:00 PM	40%	40%	0%	100%	100%	5%	100%	100%	5%
1:00 PM	2:00 PM	40%	40%	0%	100%	100%	5%	100%	100%	5%
2:00 PM	3:00 PM	40%	40%	0%	100%	100%	5%	100%	100%	5%
3:00 PM	4:00 PM	40%	40%	0%	100%	100%	5%	100%	100%	5%
4:00 PM	5:00 PM	40%	40%	0%	100%	100%	5%	100%	100%	5%
5:00 PM	6:00 PM	20%	60%	0%	100%	100%	5%	100%	100%	5%
6:00 PM	7:00 PM	5%	60%	0%	20%	100%	5%	20%	100%	5%
7:00 PM	8:00 PM	1%	60%	0%	5%	100%	5%	5%	100%	5%
8:00 PM	9:00 PM	0%	20%	0%	5%	100%	5%	5%	100%	5%
9:00 PM	10:00 PM	0%	1%	0%	5%	20%	5%	5%	20%	5%
10:00 PM	11:00 PM	0%	0%	0%	5%	5%	5%	5%	5%	5%
11:00 PM	12:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%

Non-Gallery Spaces

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday	Closed / Holiday	Weekday	Closed / Holiday	Weekday	Closed / Holiday
12:00 AM	1:00 AM	0%	0%	5%	5%	5%	5%
1:00 AM	2:00 AM	0%	0%	5%	5%	5%	5%
2:00 AM	3:00 AM	0%	0%	5%	5%	5%	5%
3:00 AM	4:00 AM	0%	0%	5%	5%	5%	5%
4:00 AM	5:00 AM	0%	0%	5%	5%	5%	5%
5:00 AM	6:00 AM	0%	0%	5%	5%	5%	5%
6:00 AM	7:00 AM	0%	0%	5%	5%	5%	5%
7:00 AM	8:00 AM	10%	0%	10%	5%	10%	5%
8:00 AM	9:00 AM	20%	0%	20%	5%	20%	5%
9:00 AM	10:00 AM	40%	0%	40%	5%	40%	5%
10:00 AM	11:00 AM	75%	0%	75%	5%	75%	5%
11:00 AM	12:00 PM	90%	0%	90%	5%	90%	5%
12:00 PM	1:00 PM	60%	0%	60%	5%	60%	5%
1:00 PM	2:00 PM	90%	0%	90%	5%	90%	5%
2:00 PM	3:00 PM	90%	0%	90%	5%	90%	5%
3:00 PM	4:00 PM	90%	0%	90%	5%	90%	5%

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday	Closed / Holiday	Weekday	Closed / Holiday	Weekday	Closed / Holiday
4:00 PM	5:00 PM	90%	0%	90%	5%	90%	5%
5:00 PM	6:00 PM	60%	0%	60%	5%	60%	5%
6:00 PM	7:00 PM	15%	0%	15%	5%	15%	5%
7:00 PM	8:00 PM	0%	0%	5%	5%	5%	5%
8:00 PM	9:00 PM	0%	0%	5%	5%	5%	5%
9:00 PM	10:00 PM	0%	0%	5%	5%	5%	5%
10:00 PM	11:00 PM	0%	0%	5%	5%	5%	5%
11:00 PM	12:00 AM	0%	0%	5%	5%	5%	5%

Café

Hour		Occupancy			Lighting			Misc. Equipment		
From	To	Open (6 days)	Close/ Wed	Thurs	Open (6 days)	Closed / Wed	Thurs	Open 6 Days	Closed / Wed	Thurs
12:00 AM	1:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
1:00 AM	2:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
2:00 AM	3:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
3:00 AM	4:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
4:00 AM	5:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
5:00 AM	6:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
6:00 AM	7:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%
7:00 AM	8:00 AM	0%	0%	0%	100%	5%	100%	100%	5%	100%
8:00 AM	9:00 AM	0%	0%	0%	100%	5%	100%	100%	5%	100%
9:00 AM	10:00 AM	1%	0%	1%	100%	5%	100%	100%	5%	100%
10:00 AM	11:00 AM	35%	0%	35%	100%	5%	100%	100%	5%	100%
11:00 AM	12:00 PM	50%	0%	50%	100%	5%	100%	100%	5%	100%
12:00 PM	1:00 PM	80%	0%	80%	100%	5%	100%	100%	5%	100%
1:00 PM	2:00 PM	60%	0%	60%	100%	5%	100%	100%	5%	100%
2:00 PM	3:00 PM	20%	0%	20%	100%	5%	100%	100%	5%	100%
3:00 PM	4:00 PM	20%	0%	20%	100%	5%	100%	100%	5%	100%
4:00 PM	5:00 PM	20%	0%	20%	100%	5%	100%	100%	5%	100%
5:00 PM	6:00 PM	5%	0%	30%	100%	5%	100%	100%	5%	100%
6:00 PM	7:00 PM	0%	0%	50%	15%	5%	100%	15%	5%	100%
7:00 PM	8:00 PM	0%	0%	30%	5%	5%	100%	5%	5%	100%
8:00 PM	9:00 PM	0%	0%	20%	5%	5%	15%	5%	5%	15%
9:00 PM	10:00 PM	0%	0%	0%	5%	5%	5%	5%	5%	5%
10:00 PM	11:00 PM	0%	0%	0%	5%	5%	5%	5%	5%	5%
11:00 PM	12:00 AM	0%	0%	0%	5%	5%	5%	5%	5%	5%

Wattis Theater

Hour		Occupancy		Lighting		Misc. Equipment	
From	To	Weekday	Event	Weekday	Event	Weekday	Event
12:00 AM	1:00 AM	0%	0%	5%	5%	5%	5%
1:00 AM	2:00 AM	0%	0%	5%	5%	5%	5%
2:00 AM	3:00 AM	0%	0%	5%	5%	5%	5%
3:00 AM	4:00 AM	0%	0%	5%	5%	5%	5%
4:00 AM	5:00 AM	0%	0%	5%	5%	5%	5%
5:00 AM	6:00 AM	0%	0%	5%	5%	5%	5%
6:00 AM	7:00 AM	0%	0%	5%	5%	5%	5%
7:00 AM	8:00 AM	0%	0%	5%	5%	5%	5%
8:00 AM	9:00 AM	0%	0%	5%	5%	5%	5%
9:00 AM	10:00 AM	0%	0%	5%	5%	5%	5%
10:00 AM	11:00 AM	0%	0%	5%	5%	5%	5%
11:00 AM	12:00 PM	0%	0%	5%	5%	5%	5%
12:00 PM	1:00 PM	0%	0%	5%	5%	5%	5%
1:00 PM	2:00 PM	0%	20%	5%	65%	5%	20%
2:00 PM	3:00 PM	0%	25%	5%	65%	5%	25%
3:00 PM	4:00 PM	0%	85%	5%	100%	5%	85%
4:00 PM	5:00 PM	0%	95%	5%	100%	5%	95%
5:00 PM	6:00 PM	0%	95%	5%	100%	5%	95%
6:00 PM	7:00 PM	0%	95%	5%	100%	5%	95%
7:00 PM	8:00 PM	0%	95%	5%	100%	5%	95%
8:00 PM	9:00 PM	0%	15%	5%	30%	5%	15%
9:00 PM	10:00 PM	0%	0%	5%	5%	5%	5%
10:00 PM	11:00 PM	0%	0%	5%	5%	5%	5%
11:00 PM	12:00 AM	0%	0%	5%	5%	5%	5%

Appendix F: HVAC System Parameters

Basic Zone Parameters

Proposed Building Minimum Flow Ratio: 0.1 (Minimum allowable supply air flow rate for VAV system)
Baseline Building Minimum Design Flow: 0.4 cfm/ft^2

Design Conditions

Space (AHU)	Winter temp °F	Summer temp °F	High RH%	Low RH%
Galleries, conservation, storage	72.5 – 2.5	72.5 + 2.5	50 + 5%	50 - 5%
Administrative (Office) Space	70	75	-	-
Mechanical & Electrical Rooms	-	85		
Cold Rooms	-	40 +/- 4	40 + 5%	40 - 5%

Description of the Proposed Building and Baseline Building System Parameters

Building Element	Baseline Building	Proposed Building
Mechanical Systems		
HVAC System Type	ASHRAE 90.1-2007 Appendix G Table G3.1.1A and G3.1.1B System Type 7: Variable air volume system with hot water reheat with steam humidifiers Spaces with conditioning criteria "A" Constant Air Volume system (CAV) per LEED Interpretation (ID: 10047) www.usgbc.org/leed-interpretations?keys=10047Wattis Theater System, 11th floor Elev. Control Room, Server Room and IT room ASHRAE 90.-2007 Except B System Type 3 Packaged Single Zone AC (DX cooling, Fossil Fuel Furnace Heating)	Existing + New Addition AHU 1, 2, 3 – Dual-duct dual fan system with direct evaporative humidification 4 water source heat pumps serving Server room, elevator machine room.
Air Distribution System	Overhead mixed air distribution	Same as baseline
Design Supply Air Temperature Differential	20°F	20°F
Total Building Ventilation Air Flow Rate	100,058 cfm	101,062 cfm
Air-side System		
Cooling		
AHU Minimum Supply Temperature	55°F (based on a 20°F design delta T)	52.3°F (based on a 20°F design delta T)
AHU Cooling Source	Chilled water	Chilled water from on-site chillers

Cooling Efficiency	Wattis theater system EER 10.1	n/a
Cool Control	Supply temperature reset based on warmest zone (5 °F rise over minimum supply air temperature)	None
Heating		
Zone Heat Source	Hot water (VAV Reheat box) for all AHUs	None
Heating Efficiency	Wattis theater system 80% thermal efficiency	n/a
AHU Maximum Supply Temperature (°F)	95°F	95°F
Zonal Reheat Delta T (°F)	45°F maximum	n/a
Heat Control	Constant	None
Air-Side Economizer		
Economizer Cycle	Yes	Yes
Outside Air Control	Dry Bulb Temperature	Enthalpy
Dry Bulb High Limit	75˚F	75˚F
Enthalpy Lower Limit	n/a	25.4 Btu
Fan Power		
Supply Fan Power (kW/CFM) OR TSP	System 7-0b Basement : 0.001218 System 3 Exep B: 0.000801 System 7-1b: 0.001218 System 7-2b: 0.001244 System 7-3b: 0.001244 System 7-4b: 0.001244 System 7-5b: 0.001244 System 7-6b: 0.001348 System 7-7b: 0.001225 System 7-8b: 0.001235 System 7-9b: 0.001235 System 7-10b: 0.001244 System 3-11b: 0.001373 System 7-1a First Floor : 0.001225 System 7-2a: 0.001235 System 7-3a: 0.001244 System 7-4a: 0.001218 System 7-5a: 0.001235 System 7-6a: 0.001235 System 7-7a: 0.001244 Cold Storage System: 0.000835 Excep G3.1.1B-1: 0.000850 Excep G3.1.1B-2: 0.000850 Excep G3.1.1B-3 0.000850	Existing north - AHU-1: 0.0008195 kW/cfm Existing south - AHU-2: 0.0008195 kW/cfm New Addition - AHU-3: 0.0008195 kW/cfm

Fan Power Exhaust	Same as Proposed	Kitchen Exh – 4875 cfm @ 0.000472 kW/cfm (CAV)Toilet Exh – 15,000 cfm @ 0.000043 kW/cfm (VSD) Conservation Exh – 6,450 cfm @ 0.000342 kW/cfm (VSD) Spray Booth Exh – 5,770 cfm @ 0.000320 kW/cfm (VSD)
Fan Placement	Same as Proposed	Blow through
Fan Control	Fan EIR FPLR	Variable volume supply AHU-1: VSD AHU-2: VSD AHU-3: VSD
Fan EIR Curve	ASHRAE Fan curve 90.1-2007	Variable frequency drive for all AHUs
Outside Air		
Demand-Controlled Ventilation	Gallery spaces, conference rooms as required by ASHRAE 90.1-2007.	In Gallery spaces, conference rooms, meeting rooms, board room, conservation area per code.
Water side systems		
Cooling System		
Cooling Type	Two (2) equally sized water cooled screw chillers	2 Existing centrifugal chillers: 371 tons (4.4 MBtu) each 1 new water cooled scroll chiller 98 tons N+1 Redundancy
Central Plant Cooling Efficiency (COP)	COP 5.5	Existing chiller: COP 6.59 New chiller: COP 5.715 WSHP-1: EER 13.3 WSHP-3: EER 17.3 WSHP-4: EER 16.2
Chilled Water Temperature (°F) and Delta T (°F)	Primary CHW Loop: 44°F / 12°F	42°F / 22.6 °F
CHW Pump Power	Baseline CHW: 22W/gpm	3 chilled water pumps (two existing & one new) 16 BHP each
Secondary CHW Pump Controls and Configuration	Variable speed secondary pumps, primary pumps riding the pump curve	One speed control for existing chiller Variable speed drive for new chiller Premium efficiency motors
Chilled Water Reset Schedule	OA reset per ASHRAE 90.1-2007	Fixed
Heat Rejection System		
Heat Rejection	Open tower	3 open towers Efficiency: 0.543 kW/ton Capacity: 472 tons each
Condenser Water Temperature (°F) and Delta T (°F)	85 °F / 10 °F	72.8 °F / 15.8 °F
Fan Power	Auto sized	13 kW with premium efficiency motor
Fan Control	Two speed fans	Varaible speed control wotj VFD.

CW Pump Power	Baseline CW: 19W/gpm	3 condenser water pumps (two existing & one new) 13 HP each
Pump Controls & Configuration	One speed interlocked with chillers	One speed pump Premium efficiency motors
CW Reset Schedule	Fixed	Fixed

Heating System		
Heating Type	Two (2) natural gas fired hot water boilers	3 condensing boilers – N+1 Redundancy Aerco BMK 3000
Central Plant Heating Efficiency	80% thermal efficiency	93.3%
Hot Water Temperature (°F) and Delta T (°F)	Primary HW loop: 180°F / 50°F	160°F / 66°F
HW Pump Power	Baseline HW: 19W/gpm	3 pumps 2.7 bhp each
Secondary HW Pump Controls and Configuration	Variable speed secondary pumps	Variable speed drive Premium efficiency motors
Hot Water Reset Schedule	OA reset per ASHRAE 90.1-2007	Fixed
Domestic Hot Water (DHW)		
DHW Heater Type	Electric heater	Electric storage hot water heaters 98% thermal efficiency with condenser water reheat
DHW Supply Temperature (°F)	Same as proposed	135°F
DHW Flow Rate (GPM)	Same as proposed	2.25

Appendix G: Utility Rates

Electricity:
PG&E E-19
Virtual Rate: $ 0.1323/kWh

Gas:
PG&E G-NR1
Virtual Rate: $ 0.8765 / therm

Appendix H: GBCI Modeling Methodology

The following email describes the energy modeling methodology for the project as established by GBCI for this project.

From: Gail Hampsmire <ghampsmire@usgbc.org>
Sent: Monday, June 11, 2012 3:11 PM
To: Shruti Kasarekar; Emma Marchant
Cc: Nicolette Mueller; Elizabeth Thompson
FW: 1000018682 - SF MOMA Addition, LEED-NC 2009, EAp2 - 06/07/2012 Meeting Notes

Dear Emma,

Below are the meeting notes for our June 7 phone conference. Please let us know if you have any questions or suggested edits to the meeting notes:

Project: 1000018682 -SF MOMA Addition

Meeting Topic:
Energy modeling of the addition given that a portion of the addition shares HVAC air handling units with the existing building.

Meeting Attendees:

Nicolette Mueller
Elizabeth
Thompson Gail
Hampsmire Emma
Marchant Shruti
Kasarekar

Meeting Notes:

- GBCI walked through the 2009 Edition LEED Commercial Interiors Reference Guide and the Advanced Energy Modeling for LEED Manual modeling guidance for modeling spaces that are within the LEED project boundary and are served by HVAC systems that also serve spaces outside of the LEED project boundary. GBCI confirmed that the modeling approach is intended to calculate the energy savings attributed to the spaces within the LEED project boundary, and is not intended to penalize the project for the energy performance in the existing building spaces. Note that for LEED for New Construction, the project team must use Appendix G as the basis for documenting savings (not ASHRAE 90.1 Section 11). Also, it appears based on the project team description of the project that the lighting, process equipment, and envelope should be modeled identically in the Baseline and Proposed Case for the segment area (the area of the energy model that is outside of the LEED project boundary).
- ASHRAE 90.1-2007 indicates that one air handling unit shall be modeled per floor. However, given that the addition is considered a distinctly separate "building" from the existing building, and the building includes two distinct wings that have distinctly different schedules, the project team should model one air handling unit serving each wing per floor. The zones for each floor allocated to each air handler would be expected to be similar to the zones within a floor served by different VAV air handlers in the proposed case.
- It is acceptable to use the Building Area Method to model lighting and equipment in the segment area even if the space-by-space method is used for the spaces within the LEED boundary.

- LEED Intepretation #100001172 revises the Equation 1 formula for situations (such as this project) where the project scope of work includes major renovations to the central plant. Additional revisions are required to appropriately calculate the full energy consumption versus the HVAC-only savings calculated for EAc1.3.

Please see below for further information on the submetering within the energy model, and proration of central plant energy that should be used in order to document project compliance. This information is supplemental to the 2009 Edition LEED for Commercial Interior Reference Guide and the Advanced Energy Modeling Guide for LEED to document how the CI methodology is expanded for LEED for New Construction:
The following shall be submetered in the energy model as project-specific loads ($ENERGY_{inProject}$):

- The energy consumption (electricity and fossil fuel if applicable) for all air handling units that exclusively serve the area within the LEED project boundary. (thermal energy such as chilled water and hot water does not need to be separately metered)
- All non-HVAC loads for the area within the LEED project boundary including but not limited to:
    - Interior Lighting
    - Exterior Lighting
    - Receptacles
    - Process Loads (including elevators/escalators)
    - Any water heating equipment that is within the LEED project boundary, and serves only the areas within the LEED project boundary

The following should be separately submetered in the energy model:

- The energy consumption (electricity and fossil fuel if applicable) for all air handling units that serve both areas within and areas outside of the LEED project boundary (e.g. fan energy consumption, furnace energy consumption if a fossil fuel furnace is used, cooling consumption if a DX unit, etc.) ($ENERGY_{existAHUs}$)
- The energy consumption (electricity and fossil fuel) for the central plant (i.e. chillers, boilers, heat rejection, pumps, etc.) ($ENERGY_{PLANT}$)

The following building areas must be used to calculate the total energy consumption, total cost, and total energy savings allocated to the LEED project:

- Total Conditioned Area within the LEED Project Boundary (A_P)
- Total Conditioned Area within the LEED Project Boundary that is served by existing AHUs (A_E)
- Total Conditioned Area served by AHUs that serve both areas within and areas outside of the LEED project boundary (A_{AHU}).
- Total building conditioned area served by the central plant (APLANT)

The total energy consumption per energy type allocated to the building for both the Baseline and Proposed Case shall be the sum of:

- The project-specific energy consumption per energy type ($ENERGY_{inProject}$)
- The energy consumption for existing AHUs that also serve the project space multiplied by the total conditioned area within the LEED project boundary that is served by existing AHUs, divided by the total conditioned building area served by the same existing AHUs ($ENERGY_{existAHUs} \times A_E / A_{AHU}$)
- The energy consumption for the central plant multiplied by the total conditioned area within the LEED project boundary, divided by the total conditioned building area served by the central plant ($ENERGY_{PLANT} \times A_P / A_{PLANT}$)

As an alternative to the above method, the project team may opt to allocate the central plant energy to the project based on the average efficiency of the central plant, and the submetered thermal energy serving the project. In this case, the thermal energy for all air handlers serving the area within the LEED project boundary must be submetered in the energy model, and the output reports indicating the total thermal energy generated by the central plant shall be provided with the LEED documentation. The average efficiency for each central plant thermal energy source per energy type (e.g. electricity / fossil fuel) shall be determined by dividing the annual energy generated by the central plant by the annual energy consumption per energy type for the central plant. The total energy consumption per energy type allocated to the building for both the Baseline and Proposed Case shall be the sum of:

- The project-specific energy consumption per energy type ($ENERGY_{inProject}$)
- The energy consumption for existing AHUs that also serve the project space multiplied by the total conditioned area within the LEED project boundary that is served by existing AHUs, divided by the total conditioned building area served by the same existing AHUs ($ENERGY_{existAHUs} \times A_E / A_{AHU}$)
- The average efficiency of the central plant equipment multiplied by the thermal energy metered for the existing air handlers serving the project space, multiplied by the total conditioned area within the LEED project boundary that is served by existing AHUs, divided by the total conditioned building area served by the same existing AHUs ($AveragePlantEfficiency \times ThermalEnergy_{ExistingAHUs} \times A_E / A_{AHU}$)
- The average efficiency of the central plant equipment multiplied by the thermal energy metered for the new air handlers that exclusively serve the project space ($AveragePlantEfficiency \times ThermalEnergy_{NewAHUs}$)

The energy costs for the LEED project (the SF Moma Addition) shall be determined based on the virtual energy rates per energy type for the full building energy model, multiplied by the energy consumption per energy type for the LEED project area as identified above.

As you are preparing your documentation, please don't hesitate to ask if you have further questions about how to apply these formulas. Please also upload this e-mail with your EAp2 documentation to LEED Online.

Gail Hampsmire, *P.E., LEED AP BD+C*
Technical Director, HVAC/Energy Team

Green Building Certification Institute
2101 L Street NW I Suite 650 I Washington DC
20037

Main: 1.202.742.3232 I fax: 202.828.5110 I email: ghampsmire@gbci.org

Appendix I: Lighting Power Density & Fan Power Calculations

Ambient LPDs for gallery spaces:

5341 - SF MoMA
Ambient Lighting Power Density Calculations
Galleries

Luminare Tag	Watts per Luminaire	# of Luminaires	Total Installed Watts	Floor	Space	Area (sf)	LPD (W/sf)
				4	Fisher Gallery (Sculpted Ceiling)		
			13,920	4	Fisher Destination Gallery		
				5	Fisher Gallery (Sculpted Ceiling)		
AC1	5	5,568	13,920	5	Fisher Destination Gallery		
AC9	5	61	305		Fisher Gallery Skylight	27,500	1.0
AC2	7	283	1,981		Restrooms		
AD2	14	92	1,288	All	Restrooms		
AH5	2.5	155	388		Restrooms		
AW1	5	146	730		Restrooms	6,037	0.7
AC3	5	35	175	1	Event Lobby		
AD11	22	48	1,056	1	Event Lobby	1,660	0.7
AC5	5	54	270	5	Atrium Gallery	3,110	0.1
				6	Fisher Gallery (Flat Ceiling)		
				6	Fisher Destination Gallery		
AC6	5	2,508	12,540	6	Architecture & Design	13,160	1.0
AC8	12	141	1,692	4			
AD4	22	272	7,986	4			
AH4	2.5	218	546	5			
AW2	28	17	476	6	City Gallery & Stairs	5,055	2.1
AD5	22	16	352				
AD11	22	21	462	1	Admin Entry	960	0.8
				7	Media Arts Special Exhibition	2,770	
AD8	60	116	6,960	7	Media Arts Collection	1,640	1.6
AD9	22	102	2,244	3	Calder Gallery	2,900	0.8
					White Box	3,120	
AD10	60	24	1,440	4	Under Bridge Gallery	470	0.4
				7	Contemporary Painting & Sculpture	8,750	
AL1	17	460	7,820	7	Elevator Lobby	442	0.9
AR1	8.4	100	840	2	Seminar	1,180	
AR2	8.4	42	353	2	Seminar	760	
AH3	2.5	118	294	2	Seminar Rooms, Education Office,	1,180	0.5
AR3	8.4	268	2,248	2	Multipurpose Room	2,870	0.8
AR4	8.4	1,222	10,265	1	Howard Street, Lobby, Ticket Lobby,	18,000	0.6
AR5	8.4	40	336	2	Coat Check	840	0.4
AR8	8.4	104	874	3	Art Court, Interpretation Gallery	4,350	
AC10	5	21	105	2	Art Court Tunnel	150	0.2
AR9	8.4	36	302		Education Offices	540	0.6
no ambient lighting				3	Photo Special Exhibition	5,000	0.00
AD4	22	18	396	4	New Work	1,080	0.4
AD4	22	13	286	4	Bridge	470	0.6
AD4	22	18	396	4	Elevator Lobby	442	0.9
AD4	22	21	462	5	Elevator Lobby	442	1.0
AD4	22	21	462	6	Elevator Lobby	442	1.0
				3	Graphic Study	1,910	

Appendix J: LEED Online Issue

Atelier Ten attempted to check compliance on the Summary section of the LEED EAp2 form on LEED Online. However, it appears that the compliance with EA p2: Minimum Energy Performance results in “N” as there is a very slight difference in the values of “Receptacle Equipment”. As the difference in the receptable equipment values do not affect the results (as the difference is very small), the results and the EAp2 form are left as is.

Table EAp2-18. End Use Energy Percentage

	Baseline Case (%)	Proposed Case (%)	End Use Energy Savings (%)
Interior Lighting	13.74	22.21	4.02
Space Heating	37.77	22.1	55.77
Space Cooling	3.82	6.59	0.63
Fans - Interior	18.45	12.56	25.22
Service Water Heating	2.03	1.72	2.38
Receptacle Equipment	6.16	11.54	-0.02
Miscellaneous	18.04	23.28	12.01

ADDITIONAL DETAILS

☐ Special circumstances preclude documentation of prerequisite compliance with the submittal requirements outlined in this form.

☐ The project team is using an alternative compliance approach in lieu of standard submittal paths.

SUMMARY

EA Prerequisite 2: Minimum Energy Performance Compliance Documented: N Check Compliance

LEED 2009 for New Construction and Major Renovations
EA Prerequisite 2: Minimum Energy Performance

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Save Form

Appendix K: Results Calculation for SFMOMA Expansion per GBCI Guideline

5341 SFMOMA Expansion

Results Calculation per GBCI Guidelines

Areas Calculation for LEED-CI per GBCI Guidance:

Description	Area	Unit	Abbreviation
Total conditioned area within the LEED Project boundary that is served by	157,137	Sq. ft	Ae
Total conditioned area served by AHUs that serve both areas within and areas outside of the LEED project boundary	396,997	Sq. ft	Aahu
Total conditioned area within the LEED Project boundary	258,403	Sq. ft	Ap
Total conditioned area served by the central plant	396,997	Sq. ft	Aplant

	AVERAGE BASELINE			
	Electricity (kWh)	Elec MBTU	Gas Mbtu	Total MBTU
Energy Consumption - In Project				
New AHU Fans	450,507	1,537		1,537
In Project Ambient Lighting	739,915	2,525		2,525
In Project Exterior Lighting	143,757	490		490
In Project Receptacles	331,674	1,132		1,132
In Project Decorative + Art Lighting	652,741	2,227		2,227
Total	***2,318,594***	***7,911***	-	7,911
Energy Consumption - Existing AHU				
Existing AHU Fans	1,463,142	4,992	-	4,992
Energy (exist AHU) X Ae / Aahu	579,132.62	1,976	-	1,976
Total	***579,133***	***1,976***	-	1,976
Energy Consumption - Central Plant				
Space Cooling	315,999	1,078	156	1,234
Space Heating	-	-	10,658	10,658
Pumps	211,627	722	-	722
Heat Rejection	10,804	37	-	37
Domestic Hot Water	167,348	571	-	571
Energyplant X Ap/Aplant	459,386.63	***1,567***	7,038.70	8,606
Space Cooling	205,681.75	702	102	803
Space Heating	-	-	6,937.17	6,937
Pumps	137,746.95	470	-	470
Heat Rejection	7,032	24	-	24
Domestic Hot Water	108,926	372	-	372
Energyplant X Ap/Aplant	459,387	1,567	7,039	8,606

End Use Distribution - IN PROJECT ONLY	Electricity		Gas	Total Consumption
	kWh	Mbtu	Mbtu	MBTU
Space Cool	205,682	702	102	803
Heat Reject.	7,032	24		24
Refrigeration		-		-
Space Heat		-	6,937	6,937
HP Supp.		-		-
Hot Water	108,926	372	-	372
Vent. Fans	993,214	3,389		3,389
Pumps & Aux.	137,747	470		470
Ext. Usage	143,757	490		490
Misc. Equip.	331,674	1,132		1,132
Decorative + Art Lighting	652,741	2,227		2,227
Area Lights	739,915	2,525		2,525
Total	***3,320,688***	***11,330***	***7,039***	***18,369***

Electricity Cost	$	454,270
Natural Gas Cost	$	57,971
Total Cost	$	512,241

5341 SFMOMA Expansion
Results Calculation per GBCI Guidelines

Areas Calculation for LEED-CI per GBCI Guidance:

Description	Area	Unit	Abbreviation
Total conditioned area within the LEED Project boundary that is served	157,137	Sq. ft	Ae
Total conditioned area served by AHUs that serve both areas within and areas outside of the LEED project boundary	396,997	Sq. ft	Aahu
Total conditioned area within the LEED Project boundary	258,403	Sq. ft	Ap
Total conditioned area served by the central plant	396,997	Sq. ft	Aplant

	Proposed Case			
	Electricity (kWh)	Elec MBTU	Gas Mbtu	Total MBTU
Energy Consumption - In Project				
New AHU Fans	223,660	763	-	763
In Project Ambient Lighting	639,238	2,181	-	2,181
In Project Exterior Lighting	74,992	256	-	256
In Project Receptacles	332,143	1,133	-	1,133
In Project Decorative + Art Lighting	658,829	2,248	-	2,248
Total	***1,928,862***	***6,581***	-	6,581
Energy Consumption - Existing AHU				
Existing AHU Fans	348,739	1,190	-	1,190
Energy (exist AHU) X Ae / Aahu	138,035.93	471	-	471
Total	***138,036***	***471***	-	471
Energy Consumption - Central Plant				
Space Cooling	291,887	996	-	996
Space Heating	341	1	3,335	3,336
Pumps	193,330	660	-	660
Heat Rejection	140	0	-	0
Domestic Hot Water	76,019	259	-	259
Energyplant X Ap/Aplant	365,618.33	***1,247***	2,170.73	3,418
Space Cooling	189,987.55	648	-	648
Space Heating	222	1	2,170.73	2,171
Pumps	125,837.37	429	-	429
Heat Rejection	91	0	-	0
Domestic Hot Water	49,480	169	-	169
Energyplant X Ap/Aplant	365,618	1,247	2,171	3,418

End Use Distribution - IN PROJECT ONLY	Electricity Consumption		Gas consumption	Total Consumption
	kWh	Mbtu	Mbtu	MBTU
Space Cool	189,988	648		648
Heat Reject.	91	0		0
Refrigeration		-		-
Space Heat	222	1	2,171	2,171
HP Supp.		-		-
Hot Water	49,480	169	-	169
Vent. Fans	361,696	1,234		1,234
Pumps & Aux.	125,837	429		429
Ext. Usage	74,992	256		256
Misc. Equip.	332,143	1,133		1,133
Decorative + Art Lighting	658,829	2,248		2,248
Area Lights	639,238	2,181		2,181
Total	***2,432,516***	***8,300***	***2,171***	***10,470***

Electricity Cost	$	332,768
Natural Gas Cost	$	17,878
Total Cost	$	350,646

EA: JS / SK
REviewed by: SK, SHR
REPORT REVIEW: ST, CM

Appendix D

San Francisco Museum of Modern Art

Expansion and Renovation Project

HVAC Systems
Basis of Design

100% Construction Documents

July 31, 2013

Taylor Engineering
1080 Marina Village Parkway, Suite 501
Alameda, CA 94501
(510) 749 – 9135

1. Introduction

1.1 Purpose of this Basis of Design

The overall goal of this Basis of Design is to describe the logic and thinking behind how the HVAC systems for this project are designed.

While much of this information is contained in the project plans and specifications, those documents are intended primarily intended as tools to convey to the construction team **what** to build and **how** to build it. This document aims to describe **why** the HVAC systems are designed as they are with the intent of capturing this information in a format that will help inform anyone who wants to know the design intent behind the systems.

Understanding the design intent can be valuable for the construction team as they plan construction and build the project. This document should also prove useful for building owners/operators as they take over the building from the construction team and operate it during its life.

This document is intended to be modified as the design and construction progress so that as changes are made to the building systems design and thinking, this document evolves to reflect that as-built conditions.

1.2 Structure of this Basis of Design

There are six major sections to this document following this introduction. Each is briefly described below to provide an overview of how this document is organized.

Project Description...................................... Describes the program for the project. It sets up project requirements that the HVAC systems will need to provide.

Design Context.. Lists the codes, standards, and other influences that affect how the HVAC systems are designed.

HVAC System Design Approach................ Explains how the HVAC system design will meet the project requirements described in the earlier sections.

HVAC System Construction Approach...... Explains how the HVAC system construction requirements support the project goals and requirements described in earlier sections.

HVAC System Equipment.......................... Discusses the type of systems and equipment that are chosen for the project.

1.3 Design/Construction Approach

This project is being implemented using a “plans and spec’s” approach. A general contractor has been hired to participate during design to provide cost and constructability advice in a construction manager role. A mechanical contractor has also been engaged during design to provide design assistance to the engineers of record.

1.4 Owner Team

1.4.1 Building Owner

Name:	San Francisco Museum of Modern Art
Contact:	Jeff Phairas
Email:	jphairas@sfmoma.org
Phone:	(415) 357-4164
Address:	151 Third Street San Francisco, CA 94103

1.4.2 Owners Representative

Name:	TJ Reagan, Inc.
Contact:	Terry Reagan
Email:	terry@tjreagan.com
Phone:	(415) 905-5366
Address:	4 Embarcadero Ctr. Suite 3330 San Francisco, CA 94111

1.4.3 Commissioning Authority (3rd Party)

Name:	Enovity Inc
Contact:	Dean Francis
Email:	dfrancis@enovity.com
Phone:	(415) 974-0390 x116
Address:	100 Montgomery St. Suite 600 San Francisco, CA 94104

1.5 Design Team

1.5.1 Lead Architect

Name:	Snohetta Architecture
Contact:	Simon Ewings
Email:	simon@snohetta.com
Phone:	(646) 383-4762
Address:	25 Broadway 2nd Floor New York, NY 10004

1.5.2 Local Architect

Name:	EHDD Architecture
Contact:	Kelly Ishida Sloan
Email:	K.Sloan@ehdd.com
Phone:	(415) 285-9193

Address:	500 Treat Ave. #201 San Francisco, CA 94110

1.5.3 Conservation Specialist

Name:	Sam Anderson Architects
Contact:	Sam Anderson
Email:	sam@samuelanderson.com
Phone:	917-561-0843
Address:	307 West 38th Street Suite #1901 New York, NY 10018

1.5.4 Structural Engineer

Name:	MKA Engineers
Contact:	Greg Briggs
Email:	gbriggs@mka.com
Phone:	(206) 215-8368
Address:	1301 Fifth Avenue, Suite 3200 Seattle, Washington 98101-2699

1.5.5 Mechanical & Plumbing Engineer

Name:	Taylor Engineering
Contact:	Steve Taylor, Todd Gottshall, Bill Stahl
Email:	staylor@taylor-engineering.com
Phone:	(510) 749-9135
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1.5.6 Electrical Engineer

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1.5.7 Telecom Consultant

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1.5.8 Acoustical Consultant

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1.6 Construction Team

1.6.1 General Contractor

Name:	Webcor Builders
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1.6.2 Mechanical Contractor

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1.6.3 Controls Contractor

Name:	Not yet selected
Contact:	
Email:	
Phone:	
Address:	

1.7 Abbreviations

The abbreviations listed in the tables below are used throughout this document.

Abbreviation	Description
Project Abbreviations	
SFMOMA	San Francisco Museum of Modern Art
General Abbreviations	
EMCS	Energy Management and Control System (the computerized/network control and monitoring system)
DDC	Direct Digital Control (often used interchangeably with EMCS)
Cx	Commissioning
System Abbreviations	
CHW	Chilled Water
HW	Hot Water
DW	Domestic Water
DHW	Domestic Hot Water
HPS	High Pressure Steam
LPS	Low Pressure Steam
CR	Condensate Return
Piping Abbreviations	
CHW CHWS	Chilled Water Supply
CHWR	Chilled Water Return
CHW/R	Chilled Water Supply and Return
HW HWS	Hot Water Supply
HWR	Hot Water Return
HW/R	Hot Water Supply and Return
Temperature Abbreviations	
OAT	Outdoor Air Temperature

Abbreviation	Description
SAT	Supply Air Temperature
RAT	Return Air Temperature
MAT	Mixed Air Temperature
Measurement Abbreviations	
dP dp Δp	Differential Pressure
delta-T dT ΔT	Change in system temperature from supply to return
DB	Dry Bulb Temperature
WB	Wet Bulb Temperature
DP	Dew Point Temperature
Unit Abbreviations	
Btu	British Thermal Unit (measure of energy)
Btuh Btu/hr	Btu/hour (measure of power)
MBH	Thousand Btu/hr
MMBtu	Million Btu
GPM gpm	gallons per minute
Equipment Abbreviations	
AH-A	Air Handler A
AH-B1	Air Handler B1
AH-B2	Air Handler B2
AH-C	Air Handler C
VSD	Variable Speed Drive
VFD	Variable Frequency Drive (used interchangeably with VSD above)

2. Project Description

2.1 Purpose of this Section

The goal of this section of the Basis of Design is to describe the program of the building and important items that will affect the HVAC system design, including items such as indoor environmental criteria, expected building use, system redundancy, etc.

2.2 SFMOMA Expansion Project Description

2.2.1 Summary

The original SFMOMA building was designed in 1993 and constructed in 1995. It is referred to as the “Botta Building” after the architect Mario Botta who designed it. Flack and Kurtz Consulting Engineers were the original MEP engineers on the project. The original building area is approximately 220,000 sq.ft. distributed in a 5-story structure above grade over one level of basement with a 5-story atrium. The existing building is not a high-rise structure but the atrium required the inclusion of smoke control systems typical of high rise buildings.

This project consists of an addition to the existing museum building. The new addition consists of a 10-story high-rise building with an atrium that will become part of the existing atrium. The “administration” wing of the existing building will be demolished to make way for the addition.

Program elements for the completed project include galleries, theater, administration, library, café, event space, retail shop, art conservation studios, and storage. Completed project area is approximately 486,000 sq.ft.

2.3 Indoor Environmental Criteria

2.3.1 Gallery, Art Storage, Conservation Areas

Creating stable conditions for the protection of the artwork on display and in storage is one of the primary project goals for SFMOMA HVAC systems. At the same time, the museum has embraced aggressive energy performance goals in keeping with larger goals for the institution as well as for compliance with the City of San Francisco green building ordinance.

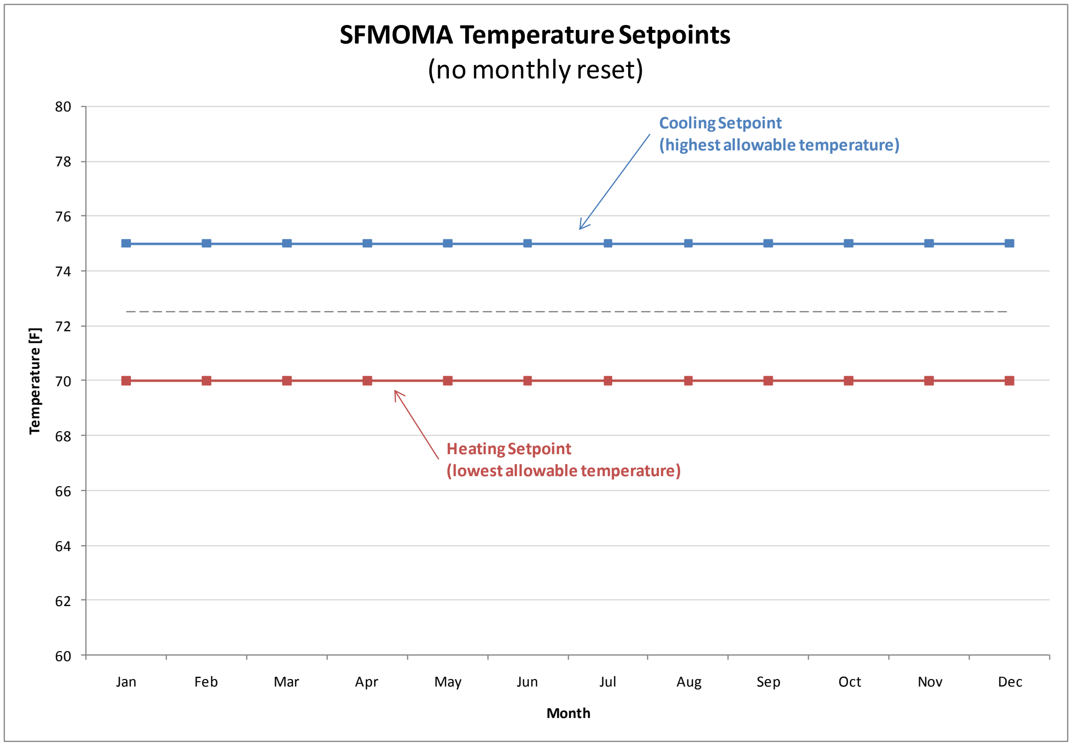
Traditional indoor environmental criteria in museums demand a high energy input to maintain very tight conditions. Current thinking in the museum artifact conservation field suggests that art can be adequately preserved in more relaxed conditions as long as the indoor temperature and relative humidity conditions do not change too quickly.

SFMOMA organized a round-table discussion including experts in the field to review the latest recommendations by the American Institute of Conservators (AIC) and consider their adoption for this project. Based on that meeting, the project has adopted the AIC recommendations as follows. For this project, these will be labeled Class “A” criteria.

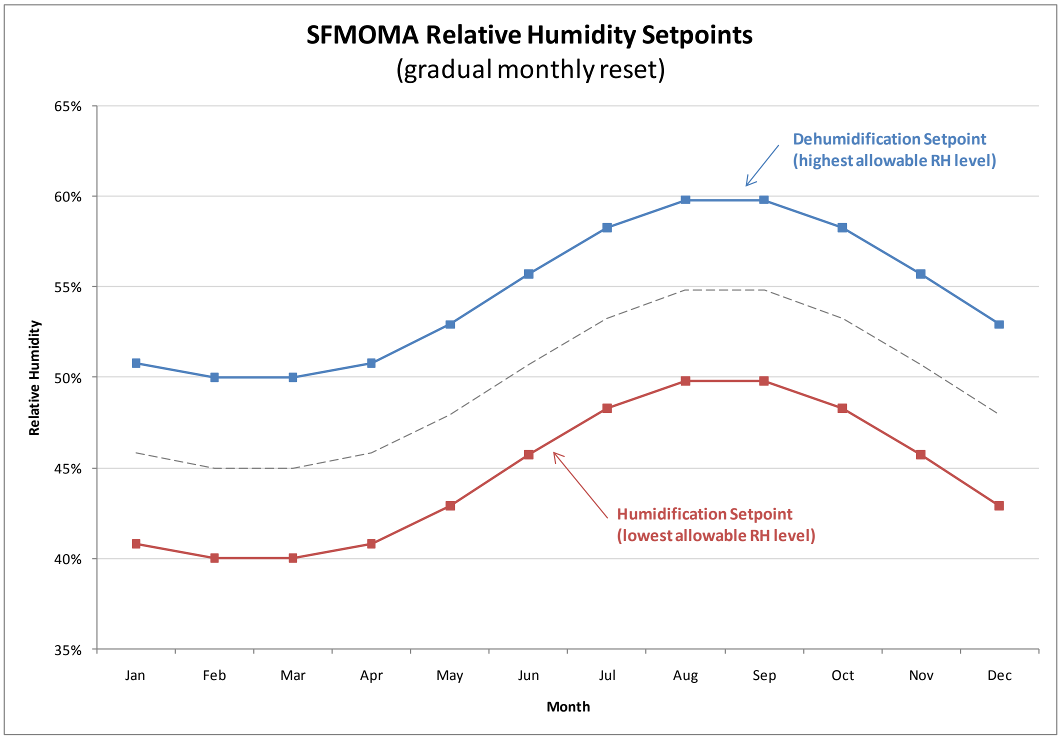
(Class A Criteria)	Heating	Cooling	Relative Humidity
Galleries, Conservation, Storage	72.5°F ± 2.5°F		50% ± 5% seasonally adjusted ± 5% per diagram below

Galleries, conservation, and art storage space conditions will be maintained continuously (24x7).

Gallery temperature conditions will be maintained per the graph below across the year.



To reduce energy costs, gallery relative humidity setpoints are gradually adjusted each month to achieve a maximum seasonal variation of 10% per the graph below.



2.3.2 Film Archive

SFMOMA houses a rare film collection that will be housed in a cold room. This cold room will be installed with a "cool" room antechamber where materials can be left for a period of time to allow them to slowly transition in temperature and moisture content between the long-term-storage areas and the museum environment. This will reduce the thermal stress on materials as well as allow them to come up to temperature to avoid condensation when moving from the cold/dry storage areas to the relatively more-humid standard museum environment. The cold and cool rooms will be conditioned by a self-contained packaged cooling unit. Heat rejection is via the closed-circuit condenser water system and moisture rejection is via an exhaust air system.

(Class AA Criteria)	Heating	Cooling	Relative Humidity
Cold Room	--	40° F± 4°F	40% RH ±5%
Cool Room (antechamber)	--	55° F± 4°F	45% RH ±5%

2.3.3 Office, Administration, Back-of-House, and Non-Gallery/Art Areas

Areas in the building that do not contain artwork will be heated and cooled to conventional temperatures for human comfort. There will be no direct humidity control in these areas.

Administrative office space conditions will be maintained during occupied periods only with setback and setup temperatures maintained during unoccupied periods for energy conservation. Ventilation will also be shut off during unoccupied periods.

These criteria are summarized in the table below. For this project, these will be labeled Class "B" criteria. Note that while Class B areas are not humidity controlled, they are served by the same AHUs as the Class A areas and hence will have similar humidity levels as Class A areas. There is little or no energy penalty for this due to the almost zero-energy humidification system described below.

(Class B Criteria)	Heating	Cooling	Relative Humidity
Administrative (Office) Space	70°F	75°F	no control

2.3.4 IT, Computer, Server Rooms

IT rooms contain equipment that requires cooling to operate effectively. These spaces will be conditioned continuously.

(Class C Criteria)	Heating	Cooling	Relative Humidity
IT, Computer Rooms	None	75°F	no control

2.3.5 Equipment Rooms, Non-Critical Spaces

Mechanical and electrical rooms contain equipment that can tolerate higher temperatures than the Class B or C conditions defined above. For energy efficiency and cost savings, these rooms are design for higher temperatures.

(Class D Criteria)	Heating	Cooling	Relative Humidity
Mechanical Rooms	None	None	no control
Electrical Rooms	None	95°F	no control
Elevator Rooms	None	85°F	no control

2.4 Building Thermal Loads

2.4.1 Internal Gains

The table below summarizes the internal heat loads used to size the HVAC systems for the project. These general numbers are superseded by more specific values on a room-by-room basis where more detailed information is available.

Occupancy	Lighting (W/ft^2)	Equipment (W/ft^2)	People		
			Density (ft^2/person)	Sensible (Btu/hr per person)	Latent (Btu/hr per person)
Gallery	3.5 to 4.5	0.25	20	250	250
Conference room	1.5	1.5	20	250	200
Copy Room	0.6	4	150	275	275
Corridor/Storage	0.6	0	200	250	250
Delivery-Shipping/Receiving	0.6	0	300	275	475
IDF/MDF/ELEC	0.7	50	0	250	200
Kitchen	1.6	10	100	275	475
Lobby	1.5	0.25	40	250	250
Office <= 250 ft^2	1.1	1.5	150	250	200
Office > 250 ft^2	0.9	1.5	150	250	200
Café	1.1	0.5	20	275	275
Retail Spaces	2.5	0.5	60	250	200
Toilet	0.8	0	300	250	250

2.4.2 Diversity

Using diversity to "right size" the HVAC systems is consistent with best industry practices. Diversity Factors for system and plant loads used for HVAC sizing area as follows.

- People: 50%
- Lights: 90%
- Plugs: 50%

2.4.3 Building Envelope Loads

2.4.3.1 Opaque Building Envelope

The building envelope constructions vary throughout the project. For simplicity we have assumed a reasonable U value of 0.14 for all opaque wall constructions and 0.05 for roofs.

2.4.3.2 Windows

The table below summarizes windows to be used throughout the project.

SF MOMA - Glass schedule					
System	Monumental Glass Structural IGU	Glass Curtain Wall Natoma Window Glass	Glass Window Wall Galleries	Glass Window Wall Admin	Glass Window Wall Bridge
	WT-1	WT-2	WT-3	WT-4	WT-5
Original Basis of Design					
Make-Up	**Glass Type GL-1** • Outer lite: Two plies of 6mm low-iron glass laminated with 1.5mm PVB interlayer with low-E coating on #4 surface (VE13-2M) • 12mm air space, • Inner lite: Four plies of 18mm low-iron glass laminated with 1.5mm PVB interlayer	**Glass Type GL-2A** • Outer lite: Two plies of 12mm low-iron glass laminated with 1.5mm PVB interlayer with low-E coating on #4 surface (VE13-2M) • 12mm air space, • Inner lite: Two plies of 12mm low-iron glass laminated with 1.5mm PVB interlayer	**Glass Type GL-3A** • Outer lite: Two plies of 6mm low-iron glass laminated with Custom pattern ceramic frit on #2 surface and 1.5mm PVB interlayer with low-E coating on #4 surface (VE13-2M) • 12mm air space, • Inner lite: Two plies of 10mm low-iron glass laminated with 1.5mm PVB interlayer	**Glass Type GL-4** • Outer lite: Two plies of 6mm low-iron glass, laminated with 1.5mm PVB interlayer with low-E coating on #4 surface (VNE13-63) • 12mm air space, • Inner lite: Two plies of 6mm low-iron glass laminated with 1.5mm PVB interlayer	**Glass Type GL-5** • Outer lite: Two plies of 8mm low-iron glass, laminated with 1.5mm PVB interlayer with custom pattern ceramic frit on surface #2 and low-E coating on #4 surface (VE13-2M) • 12mm air space, • Inner lite: Two plies of 10mm low-iron glass laminated with 1.5mm PVB interlayer
		Glass Type GL-2B (Glass Fin) • Outer lite: Three plies of 18mm low-iron glass laminated with 1.5mm PVB interlayer	**Glass Type GL-3B** • Outer lite: Two plies of 8mm low-iron glass laminated with 1.5mm PVB interlayer with low-E coating on #4 surface (VE13-2M) • 12mm air space, • Inner lite: Two plies of 10mm low-iron glass laminated with 1.5mm PVB interlayer		
			Glass Type GL-3C • Outer lite: 6mm low-iron glass with low-E coating on #2 surface (VE13-2M) • 12mm argon filled space, • Middle lite: 6mm low-iron glass with low-E coating on #4 surface • 12mm argon filled space, • Inner lite: Two plies of 6mm low-iron glass laminated with 1.5mm PVB interlayer		
Proposed DA Design					
Make-Up	**Glass Type GL-1** • Outer lite: Two plies of 6mm low iron HS glass laminated with 1.5mm SGP interlayer with low-E coating on #4 surface (VE13-2M or similar) • 12mm air space, • Inner lite: Four plies of 12mm low iron HS glass laminated with 1.5mm SGP interlayer	**Glass Type GL-2A** • Outer lite: Two plies of 6mm low iron HS glass laminated with 1.5mm SGP interlayer with low-E coating on #4 surface (VE13-2M or similar) • 12mm air space, • Inner lite: Three plies of 12mm low iron HS glass laminated with 1.5mm SGP interlayer	**Glass Type GL-3A** • Outer lite: Two plies of XX mm low iron HS glass laminated with 1.5mm SGP interlayer with low-E coating on #2 surface (VE13-2M or similar) • 12mm air space, • Inner lite: Two plies of XX mm low iron HS glass laminated with 1.5mm SGP interlayer	**Glass Type GL-4** • Outer lite: 6mm clear FT glass with low-E coating on #2 surface (VNE1-63 or similar) • 12mm air space, • Inner lite: 6mm clear FT glass	**Glass Type GL-5A** • Outer lite: Two plies of XXmm low iron HS glass, laminated with 1.5mm PVB interlayer with low-E coating on #4 surface (VE13-2M or similar) • 12mm air space, • Inner lite: Two plies of XXmm low iron HS glass laminated with 1.5mm PVB interlayer
	Glass Type GL-1; Alt. 1 • Four plies of 12mm low iron HS glass laminated with 1.5mm SGP interlayer		**Glass Type GL-3B** • Outer lite: Two plies of 8mm low iron HS glass laminated with 1.5mm SGP interlayer with low-E coating on #4 surface (VE13-2M or similar) • 12mm air space, • Inner lite: Two plies of 10mm low iron HS glass laminated with 1.5mm SGP interlayer		**Glass Type GL-5A; Alt. 1** • Outer lite: Two plies of XXmm low iron HS glass, laminated with 1.5mm PVB interlayer
			Glass Type GL-3C • Outer lite: 6mm low iron FT glass with low-E coating on #2 surface (VE13-2M or similar) • 12mm argon filled space, • Middle lite: 6mm low iron FT glass with low-E coating on #4 surface • 12mm argon filled space, • Inner lite: Two plies of 6mm low iron HS glass laminated with 1.5mm PVB interlayer		**Glass Type GL-5B** • Outer lite: Two plies of 8mm low iron HS glass, laminated with 1.5mm PVB interlayer • 12mm air space, • Inner lite: Two plies of 10mm low iron HS glass laminated with 1.5mm PVB interlayer
Performance requirements					
Accoustical Requirements[1]	STC 45	No specific requirement	White Box exterior window: STC 40	No specific requirement	Interior Bridge Glazing: STC 45 (DGU)
Colour Rendering Index (CRI)[2]	96	96	96	No specific requirement	96
UV mitigation[2]	Transmission at 400nm should be less than half of that in the middle of the visible range, at 550nm. Transmission at 320nm and at 380nm should be less than 1/100th of that at 550nm.	Transmission at 400nm should be less than half of that in the middle of the visible range, at 550nm. Transmission at 320nm and at 380nm should be less than 1/100th of that at 550nm.	Transmission at 400nm should be less than half of that in the middle of the visible range, at 550nm. Transmission at 320nm and at 380nm should be less than 1/100th of that at 550nm.	No specific requirement	Transmission at 400nm should be less than half of that in the middle of the visible range, at 550nm. Transmission at 320nm and at 380nm should be less than 1/100th of that at 550nm.
U-value	0.29	0.29	0.29	0.29	0.29
SHGC	0.39	0.39	0.39	0.29	0.39
VLT	73%	73%	73%	62%	73%

[1] STC requirements shown for reference only. Submittal of 1/3 octave band transmission loss data is required for final approval.

[2] Solar/Optical & Thermal characteristics, including spectral light transmittance information, is required for final approval.

2.4.4 Building Ventilation Loads

Building ventilation is provided as forced ventilation throughout the project per the applicable codes and standards listed in Section 3. There are no naturally ventilated spaces in this building. All spaces shall be provided with minimum ventilation in accordance with the Title 24 Building and Energy Codes.

Minimum ventilation rates are maintained at all times when spaces can reasonably expected to be occupied. During off-hours, ventilation rates are dropped to zero to reduce energy consumption in 24x7 areas. Minimum rates must be maintained when spaces are occupied under any reasonably expected thermal load condition.

CO2 sensors will be used for ventilation control in densely occupied spaces such as galleries, meeting rooms, the theater and assembly spaces.

In gallery areas, to conserve energy, ventilation rates will be dropped to zero when the rooms are unoccupied (based on occupancy sensor or schedule). Minimum recirculation rates will be maintained in Gallery and art storage areas only as required to adequately maintain uniform environmental conditions.

Private and office area toilet rooms and janitors closets will be exhausted at 75 cfm/fixture (50% above Standard 62.1) during occupied hours. Public toilet rooms will be exhausted at 100 cfm per fixture since they can be expected to be less well maintained.

2.5 Acoustics

The project is designed to meet the following noise criteria (NC) levels.

Area	Design NC
Galleries	NC 35
Media Arts Galleries	NC 30
City Galleries	NC 35
Howard Street Gallery	NC 40
White Box	NC 25
Black Box Studio	NC 30
Media Workrooms	NC 30
Conservation Lab	NC 40
Graphic Study	NC 30
Private offices	NC 30
Open offices	NC 40
General conference rooms	NC 25
Classrooms	NC 25
Boardroom	NC 25
Storage	NC 40
Corridor	NC 40
Toilet rooms	NC 40
Reception/lobby	NC 40
MDF/IDF	NA

2.6 Outdoor Environmental Design Conditions

The project will be designed to meet or exceed the indoor environmental criteria (defined above) under the following outdoor conditions.

2.6.1 Space Cooling

The following conditions represent the design outdoor temperature and enthalpy and are appropriate to use to size the space cooling loads and systems.

Dry Bulb Temperature:	**84 °F ← driver**
Wet Bulb Temperature:	65 °F
Dew Point Temperature:	53.9 °F
Source:	▪ ASHRAE Climatic Data for Region X ▪ Design Dry Bulb and Mean Coincident Wet Bulb ▪ 0.1% Yearly Exceedance ▪ San Francisco County, California

2.6.2 Evaporation / Cooling Tower

The following conditions represent a reasonably high level for outdoor air wet bulb temperature and are appropriate to use to size the evaporation loads on the cooling towers.

Dry Bulb Temperature:	78.2 °F
Wet Bulb Temperature:	**65.4 °F ← driver**
Dew Point Temperature:	50.8 °F
Source:	▪ ASHRAE 2009 Fundamentals Weather Data ▪ Evaporation Design Data ▪ 0.4% Yearly Exceedance ▪ San Francisco International Airport

2.6.3 Dehumidification

The following conditions represent a reasonably high level for outdoor air moisture and are appropriate to use to size the dehumidification loads on the system as well as the cooling towers.

Dry Bulb Temperature:	67.9 °F
Wet Bulb Temperature:	63.4 °F
Dew Point Temperature:	**61.0 °F ← driver**
Source:	▪ ASHRAE 2009 Fundamentals Weather Data ▪ Dehumidification Design Data ▪ 0.4% Yearly Exceedance ▪ San Francisco International Airport

2.6.4 Heating

The following conditions represent the design outdoor temperatures that are appropriate to use to size the space heating loads and systems.

Dry Bulb Temperature:	38 °F
Source:	▪ ASHRAE Climatic Data for Region X ▪ Heating Median of Extremes ▪ San Francisco County, California

2.7 Energy Performance

This project is designed to comply with the California Title-24 Energy Code. The project has decided to comply with the 2013 version of the energy code and plans to demonstrate compliance with the prescriptive approach.

The project also will participate in the PG&E Savings By Design program. Energy efficiency incentives have not yet been calculated for this project.

2.8 Environmental Performance

In accordance with SF Green Building Ordinance and with SFMOMA's desire for the project to excel on environmental performance, the Expansion project is designed to achieve a "Gold" rating in the US Green Building Council "Leadership in Energy and Environmental Design (LEED)" rating system. The HVAC system design plays an important role in many components of the LEED system credits.

Atelier Ten conducted a whole building energy analysis of the project at the Design Development (DD) stage, and from this analysis the performance of the new addition (inside the LEED project boundary) has been assessed. The new addition incorporates a combination of measures to reduce energy use including lower window to wall ratio, double paned glazing, insulated envelope, lower lighting power densities and energy efficient HVAC systems, including direct evaporative cooling. As a result, the Proposed Building achieves an overall reduction in energy use compared to the Baseline Building, making it 38% more efficient in terms of annual energy consumption and resulting in 14% energy cost savings.

The new addition is subject to the San Francisco Green Building Ordinance and must meet the following requirements:

- Annual energy cost reduction of 15% over an ASHRAE Appendix G Baseline Building
- Provide 1% renewable energy if performance is less than 25% reduction in energy cost savings, or purchase renewable power (LEED EAc6)
- LEED Gold certification

3. Design Context

3.1 Purpose of this Section

The goal of this section of the Basis of Design is to describe the design context for the HVAC systems. For example, this section will state the relevant codes and standards that are applicable to the project as well as any requirements or goals that go beyond the code required level, such as LEED certification or energy performance beyond Title-24 or ASHRAE 90.1.

3.2 Applicable Building Codes

California Building Code, 2013

California Mechanical Code, 2013

California Electrical Code, 2013

California Plumbing Code, 2013

California Fire Code, 2013

California Energy Code, 2013

San Francisco Green Building Ordinance, 2010

3.3 Applicable Design Standards

3.3.1 Energy

San Francisco Green Building Ordinance requires annual energy cost reduction of 15% over an ASHRAE 90.1-2007 Appendix G Baseline Building.

3.3.2 Ventilation

Ventilation systems will meet the following requirements, whichever is most stringent:

- California Energy Standards, Section 121
- Chapter 12 of the California Building Code (applies only to occupancy not covered under the California Energy Standards)
- 30% above Standard 62.1-2007 ventilation rates (LEED EAc2)

For this project, the occupant density used to determine minimum ventilation rates is determined by the industry-standard practice of using half of the space exiting density as explicitly allowed in the ventilation section of the California Energy Standards.

3.3.3 Thermal Comfort

The project will be designed consistent with ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy.

4. HVAC System Design Approach

4.1 Purpose of this Section

The goal of this section of the Basis of Design is to describe how the HVAC system design will meet the building needs and program described in previous sections. This section is an overview or "narrative" of the system design. Specific rationale for system equipment selections and for system controls approach will be provided in later sections of this document.

4.2 Primary Cooling Systems

4.2.1 Chilled Water Source

A water-cooled chiller plant is the source for all cooling in the building.

The existing 730 ton chilled water plant consists of two 365 ton centrifugal chillers. It will be augmented with an additional 100 ton chiller located in the chiller room (space was allocated in the original design for this purpose). The initial design included a third 365 ton chiller selected to match the existing for ease in staging and to improve redundancy. However, this design was value-engineered to reduce costs.

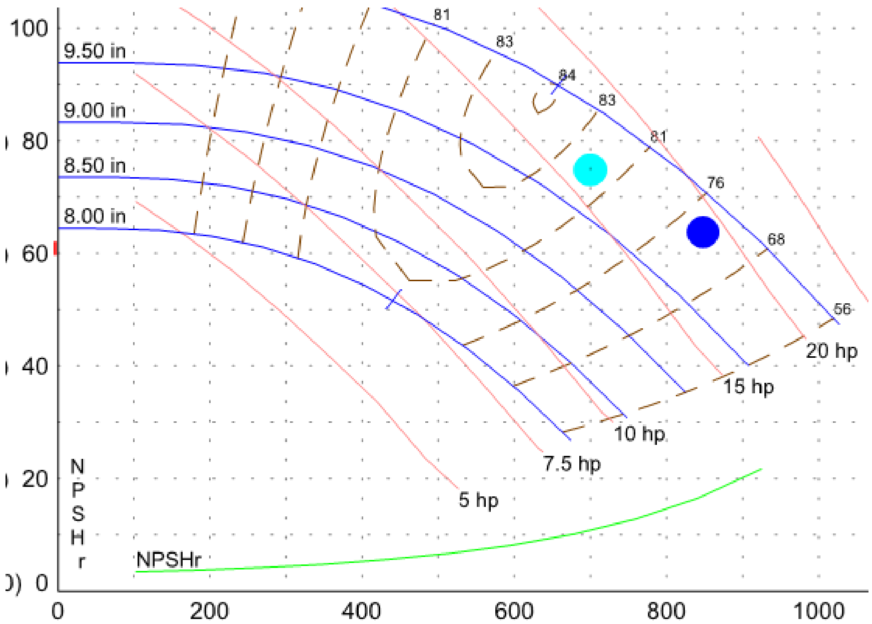
The existing chillers have been upgraded already with new VFDs and controls. No additional work will be performed as a part of the construction project but some reconditioning is expected to be done as part of the operations and maintenance budget.

4.2.2 Building Chilled Water Distribution

The existing chilled water distribution system is a primary-only variable-flow arrangement with primary chilled water pumps each sized at 700 gpm. The pumps are connected on the suction and discharge with pipe headers so that through manual or automatic control either pump can serve either chiller. In the existing plant the pumps ride their curve during variable flow operation. Minimum flow is maintained by a bypass valve located at the plant. This was not in the original design and had to be retrofitted during commissioning.

The revised plant will retain the same primary variable flow distribution system concept except the existing chilled water pumps will be retrofitted with new VFD-ready motors and variable speed drives will be installed to reduce pump energy use.

The plant is redesigned to provide 42°F chilled water (rather than the original 44°F) because it helps create high system CHW ΔT, reducing flow rates. This allows the existing piping and pumps to be reused despite the added load. It also allows the existing CHW pumps to become 100% redundant. The calculated plant load is 815 tons and about 850 gpm under design conditions. The calculated CHW pump head is 63 feet based on the new design. The existing pumps were selected for 700 gpm at 75 feet of head (they were significantly oversized). The pump curve below shows the original pump selection (700 gpm at 75 feet) for each pump and the new design flow selection assuming only one pump is on (850 gpm at 63 feet). By allowing the pump speed to increase slightly above 60 Hz, it is possible for the entire required flow to be handled by one pump with the existing 20 HP motor. (Motor current will be limited automatically by the VFD to prevent overloading the motor). So with the new design, the existing pumps can provide N+1 redundancy.



Chilled water will be distributed to existing Botta penthouse air handlers using existing risers and extended to the new air handler cooling coils in the expansion penthouse with new risers.

In order to maximize chilled water system ΔT, the system employs 2-way valves at all cooling coils. The 2-way valves also result in self-balancing. Accordingly, the system will not be manually balanced. See http://www.taylor-engineering.com/downloads/articles/ASHRAE%20Journal%20-%20Balancing%20Variable%20Flow%20Hydronic%20Systems-Taylor%20&%20Stein.pdf.

Design pressure drop across all chilled water coil control valves is 5 psi.

All chilled water piping that passes across the building seismic joint near gridline 7 will be fitted with seismic joints to allow for the expected building movement.

4.2.3 Heat Rejection

4.2.3.1 Open Condenser Water System

The existing cooling towers will be removed and replaced with new high efficiency propeller fan towers with VFDs. The new towers will be located on the upper roof adjacent to the mechanical penthouse at Level 11.

The existing condenser water riser will be reused and extended to the towers on the high roof. To allow the existing CW risers and pumps to be adequately sized for the new loads, the existing chillers were reselected for a higher CW temperature difference (lower CW flow rate) but with the same lift (CWRT minus CHWST) so that the chillers would retain their existing efficiency and impeller trim. The existing constant speed condenser water pumps will be reused and a third matching pump will be added for redundancy. This third pump will include a variable speed drive to allow it to run slower when only serving small chiller CH-3. It will also be piped to the chilled water system with manual valves to allow it to also serve as a backup chilled water pump. This should not be necessary as the CHW pumps are already fully redundant (as note above) but it was requested by the building engineer.

The condenser water system is designed with basin-sweeps in each tower and a centrifugal dirt separator to help keep the open condenser water system free of dirt.

The existing very high quality chemical water treatment system will remain in operation.

All open condenser water piping that passes across the building seismic joint near gridline 7 will be fitted seismic joints to allow for the expected building movement.

4.2.3.2 Closed Condenser Water System

The existing open-circuit condenser water system serving kitchen equipment will be converted to closed-circuit with a heat exchanger (HX-1). It will be sized to serve new kitchen water-cooled equipment, the cold room dehumidification unit, and water-cooled AC units cooling IDF rooms, plus an added 25 tons of capacity for future loads. The existing CW P-9 will be demolished and replaced with two open circuit pumps and two closed circuit pumps, each sized for 100% of the load (N+1 redundancy). The closed circuit pumps will have variable speed drives to allow them to match the load as new equipment is added to the system in the future and also to adjust flow as compressors cycle on and off – new auxiliary cooling units will have factory installed isolation valves that shut off flow when compressors shut off.

A double-walled heat exchanger (HX-2) will connect the closed-loop CW system and the incoming domestic cold water line that is connected to the domestic water heater. With this configuration we will pre-heat the water on the way to the water heater and simultaneously provide free cooling for the closed condenser water system.

All closed condenser water piping that passes across the building seismic joint near gridline 7 will be fitted with seismic joints to allow for the expected building movement.

4.3 Primary Heating Systems

4.3.1 Source

The two existing hot water boilers will be replaced with three 3,000 KBtu/h condensing boilers. The new boilers will be located in a new enclosed boiler room near the existing boiler location. The new boilers are sized to provide N+1 redundancy during other than warm-up operation.

4.3.2 Building Distribution

The new hot-water distribution system will be a primary-only variable-flow arrangement. The existing constant speed hot water pumps will be reused. Variable speed drives will not be installed since they are not cost effective on hot water systems. The pumps are connected on the suction and discharge with pipe headers so that through manual or automatic control any pump can serve any boiler.

The system will deliver hot water to the new coils in the existing heating air handlers using existing piping and to new air handlers with new piping extended to the roof. HW distribution piping will be routed close to the core spaces and above corridors, not above Gallery spaces. Minimum flow is maintained by using a single 3-way valve at AH-3A preheat coil. This is the most remote coil so the self-balancing of the system via control valves (see discussion above under section 4.2.2) will not be adversely affected.

All hot water piping that passes across the building seismic joint near gridline 7 will be fitted with seismic joints to allow for the expected building movement.

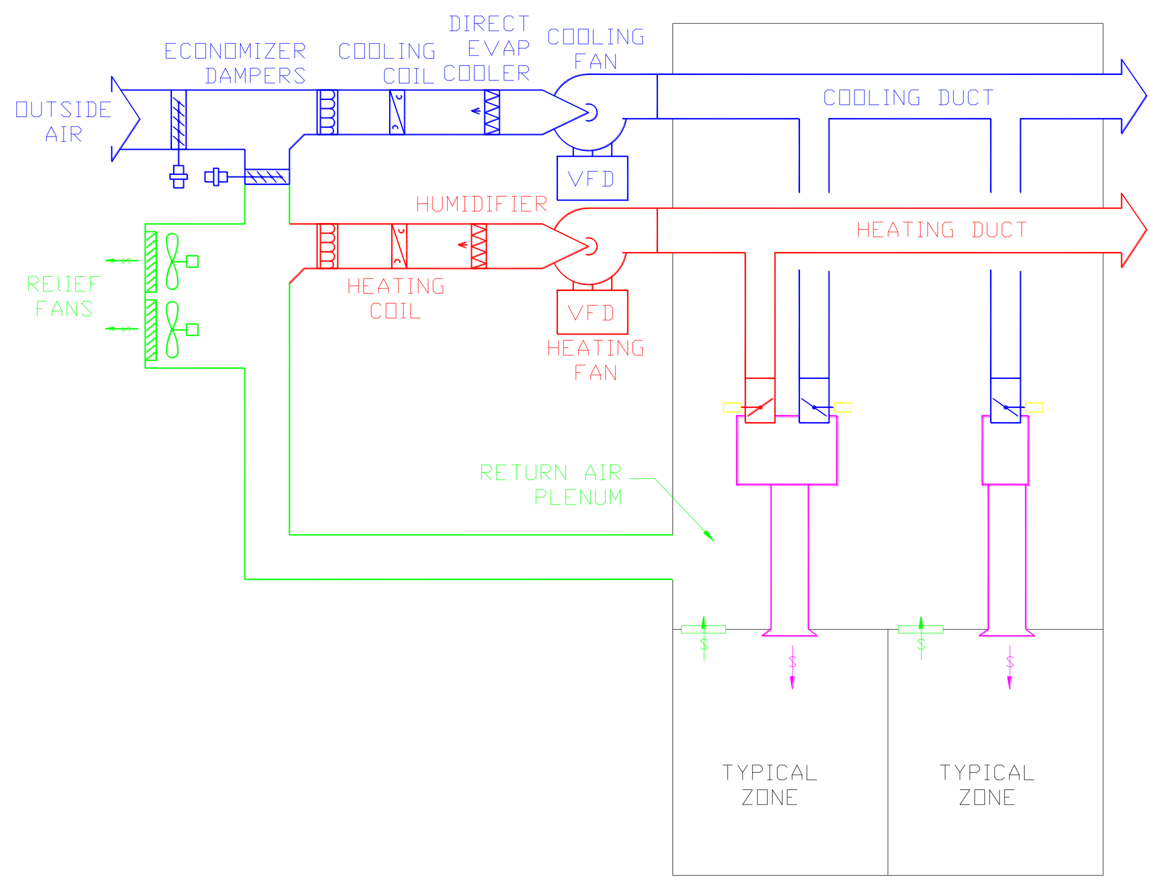
4.4 Air Distribution Systems

4.4.1 Main Air Distribution System(s)

4.4.1.1 System Description

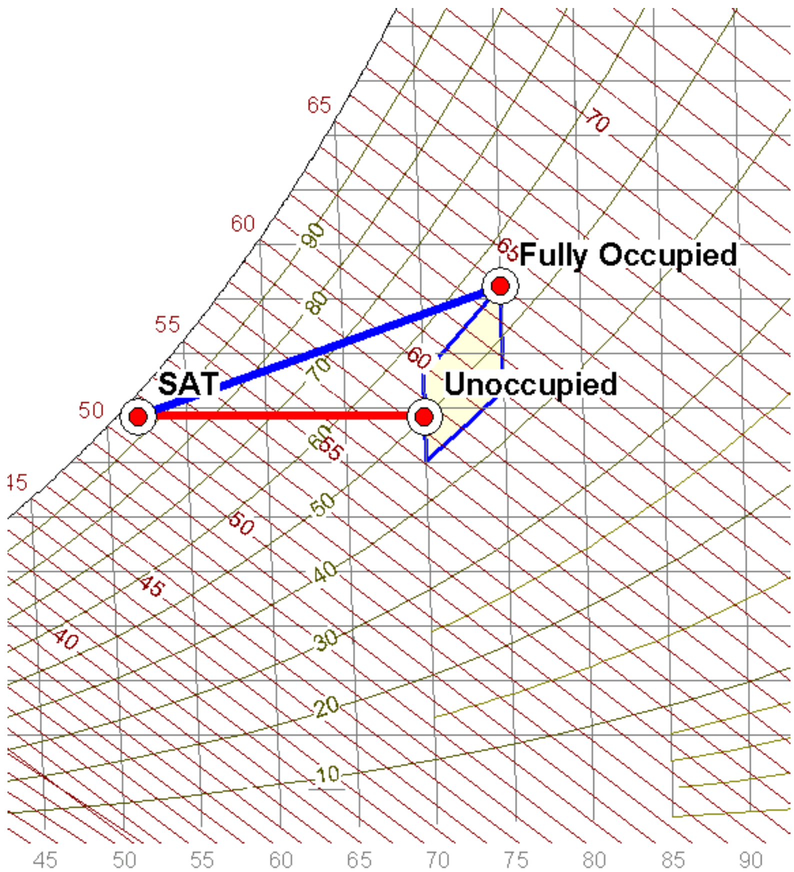
Most building space types will be served by the dual-fan dual-duct system shown in the figure below. The heating fan supplies 100% recirculated air for space heating in all zones and for tempering air for dehumidification control in Class A criteria spaces. The cooling system has both a cooling coil and a direct evaporative cooler which will provide zero-energy (adiabatic) humidification. A preheating coil (not shown in the figure below) is also provided for heating and humidifying during cold weather and low supply airflow conditions. This design allows the economizer to operate to reduce or eliminate mechanical cooling energy while not penalizing humidification energy as with conventional systems. This is the primary source of humidification during most operating conditions. Humidifiers are also provided in the heating air handler to allow the system to offset the dehumidification effect of infiltration during cold weather. No humidifiers are required at the zone level as will be demonstrated below. All humidifiers are centralized for ease of maintenance.

Dual-Fan Dual-Duct Air Handling System Diagram



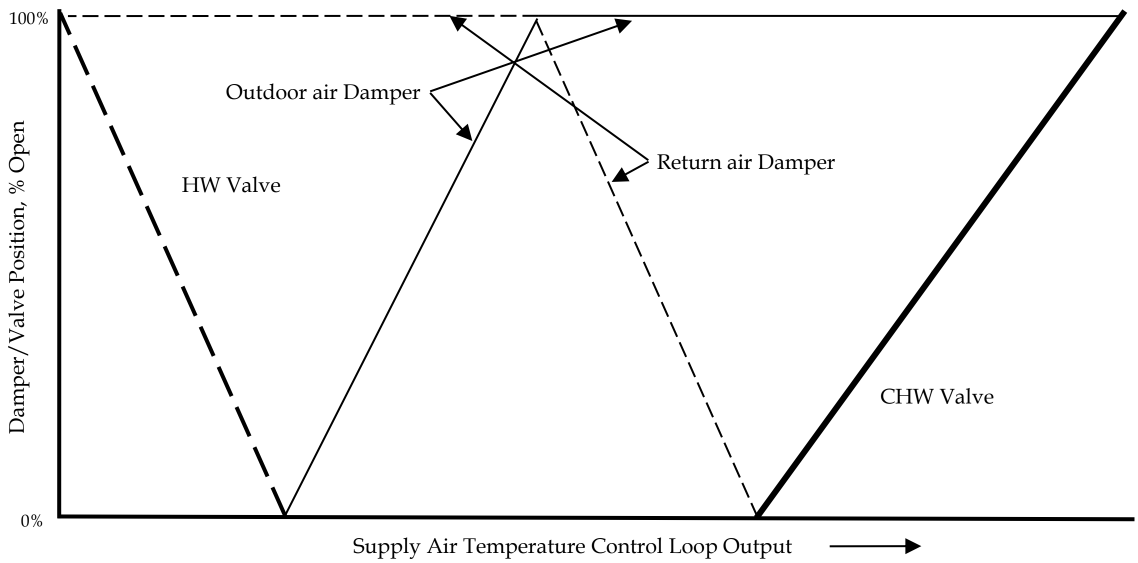
The next figure below shows basic concept behind the Class A (Gallery) system operation plotted on a psychrometric chart. The approach is to maintain a nearly constant supply air condition for a given criteria range: saturated air with a dewpoint temperature just above that at the design space temperature and lowest acceptable relatively humidity, i.e. 70ºF and 45% relative humidity for the case shown here (but adjusted based on time of year as discussed above). For zones that are unoccupied, air is warmed by space loads with no added moisture so the resulting space condition is the "Unoccupied" point in the figure. For spaces that are fully occupied, the room temperature is allowed to rise to 75ºF and with the moisture added by people, the resulting condition is the "Fully Occupied" point. Thus with a single supply air condition, all spaces can be maintained in the required temperature and humidity range.

Class A System Operation for Temperature and Humidity Control



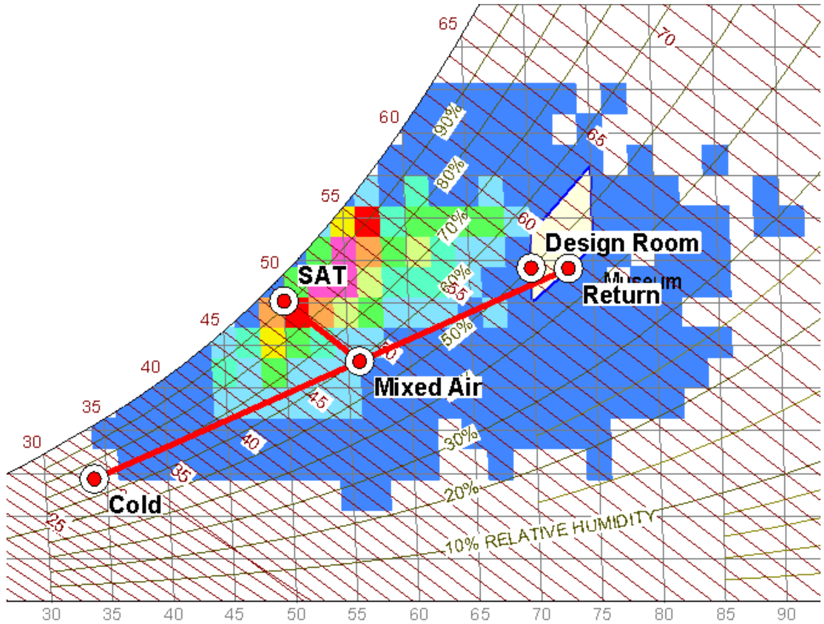
The cold deck (cooling air handler) supply air temperature is controlled as follows. The desired supply air condition is maintained with very simple control -- basically the same control sequences used for conventional VAV cooling systems. The figure below shows how the preheat coil, economizer dampers, and chilled water valve are sequenced. (Not shown are minimum outdoor air and economizer lockout logic – see Division 250000 specifications for those details. The outdoor air and return air dampers are sequenced − rather than opening one while the other closes − to reduce the pressure drop of the mixing system to save fan energy.) The addition of the direct evaporative humidifier (DEH) requires no changes to the basic control logic; it simply runs all of the time the AHU is on. (The DEH is not needed when the outdoor air humidity is below supply air dewpoint temperature but it does not hurt to use it; the air is already near saturation anyway. But to slightly reduce water usage and to allow the DEC to dry out to reduce the risk of microbial growth, the DEC can be shut off when the outdoor air dewpoint temperature is above the supply air temperature.)

Cold Deck (Cooling Air Handler) Supply Air Temperature Control



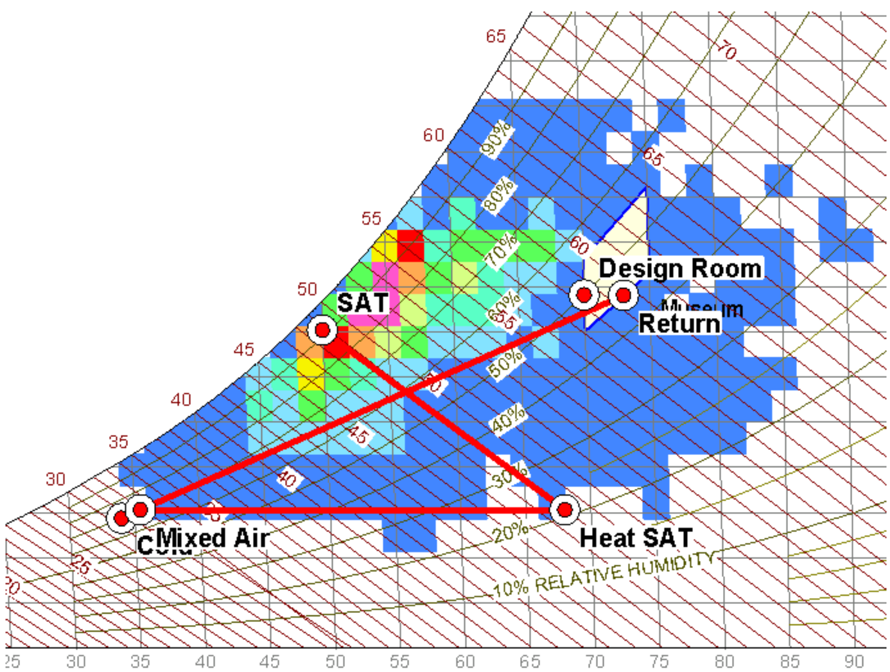
The next figure shows how the desired supply air condition is achieved in cold weather when the supply air rate is relatively high and minimum outdoor air rate is relatively low (about 40% in this example). The colored squares in the figure show the frequency of various outdoor air conditions (red is most frequent, blue is less frequent). The economizer dampers using supply air temperature control only will cause the mixed air condition to be that needed for the DEH to result in the desired saturated supply air temperature. The humidification process requires no energy (other than the small recirculation pump).

Supply Air Control – Cold Weather, High Airflow



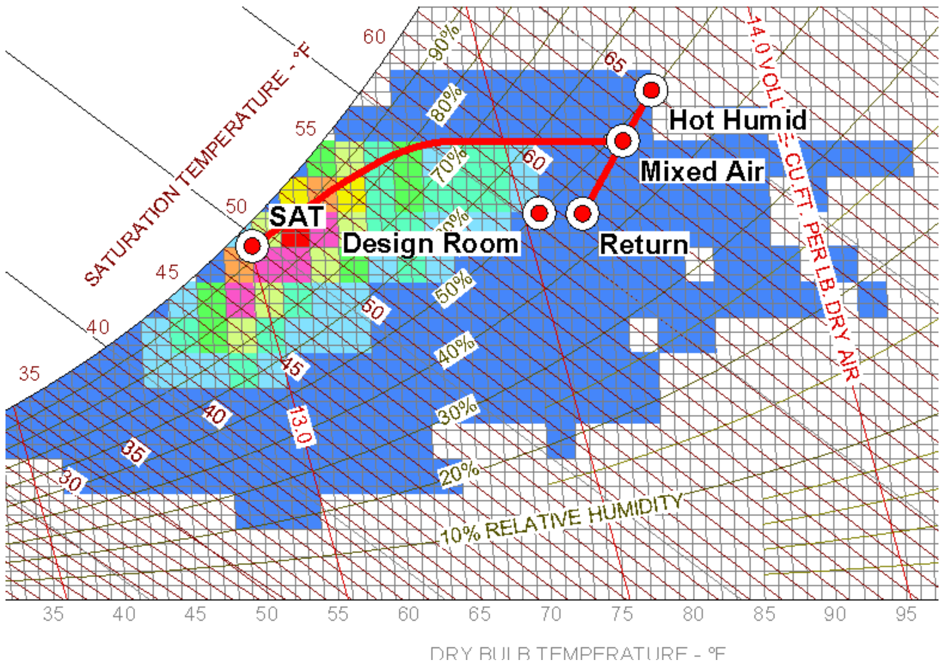
The next figure shows how the desired supply air condition is achieved in cold weather when the supply air rate is relatively low and minimum outdoor air rate is relatively high (almost 100% in this example). The supply air temperature control logic will cause the heating coil supply air temperature to be that needed for the DEH to result in the desired saturated supply air temperature. In this condition, the humidification process requires the about same amount of energy as a conventional isothermal humidifier. But this condition seldom occurs.

Supply Air Control – Cold Weather, Low Airflow



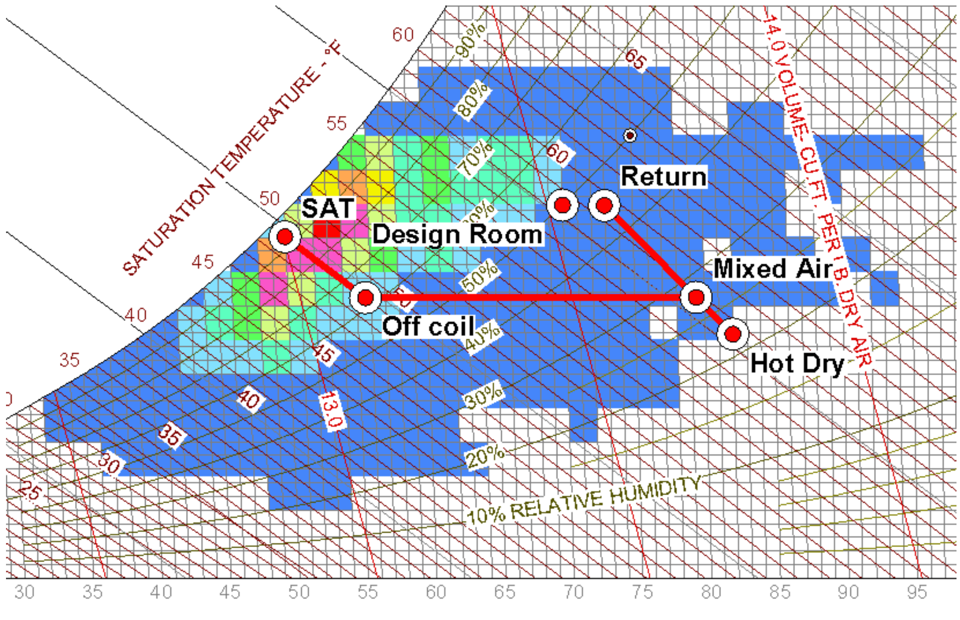
This figure shows the process when outdoor air temperature and humidity are high. In this weather, the economizer is disabled and minimum ventilation outdoor air is provided based on building ventilation demand (see ventilation discussion below). The standard cooling coil process results in the desired condition. The air leaving the coil is nearly saturated so the DEH will have little effect on the AHU leaving condition. (As noted above, it could be shut off under these conditions to help dry the media.)

<u>**Supply Air Control – Hot Humid Weather**</u>



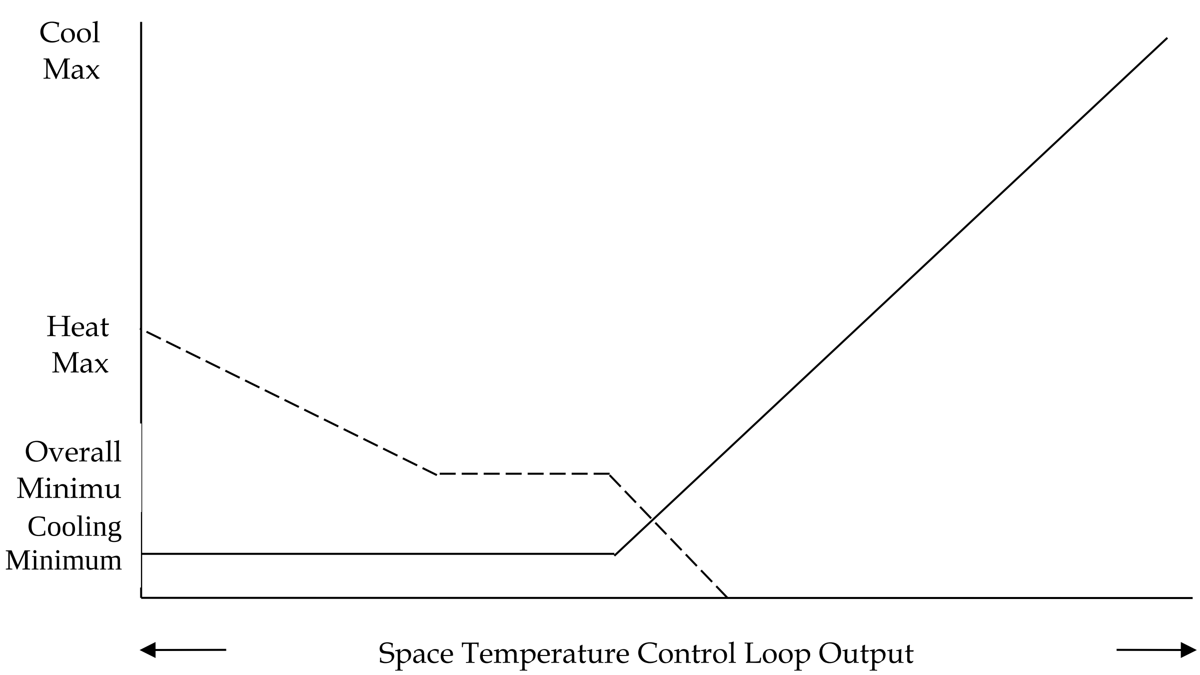
The next figure shows the process in warm, dry weather. Again, the economizer is disabled and only minimum ventilation outdoor air is supplied. The chilled water valve is, as always, controlled by supply air temperature and naturally results in the coil leaving condition required for the DEH to saturate the air and provide the desired leaving air condition.

Supply Air Control – Hot Dry Weather



Gallery zone temperature and humidity control is accomplished by resetting the VAV box cooling and heating airflow rates mapped from the output of a direct acting space temperature control loop as shown below. The space temperature loop setpoint is reset by the humidity control loop as described below. The dual duct box will have airflow sensors on both the cooling and heating supplies.

Class A (Gallery) Dual-Duct Zone Temperature Control

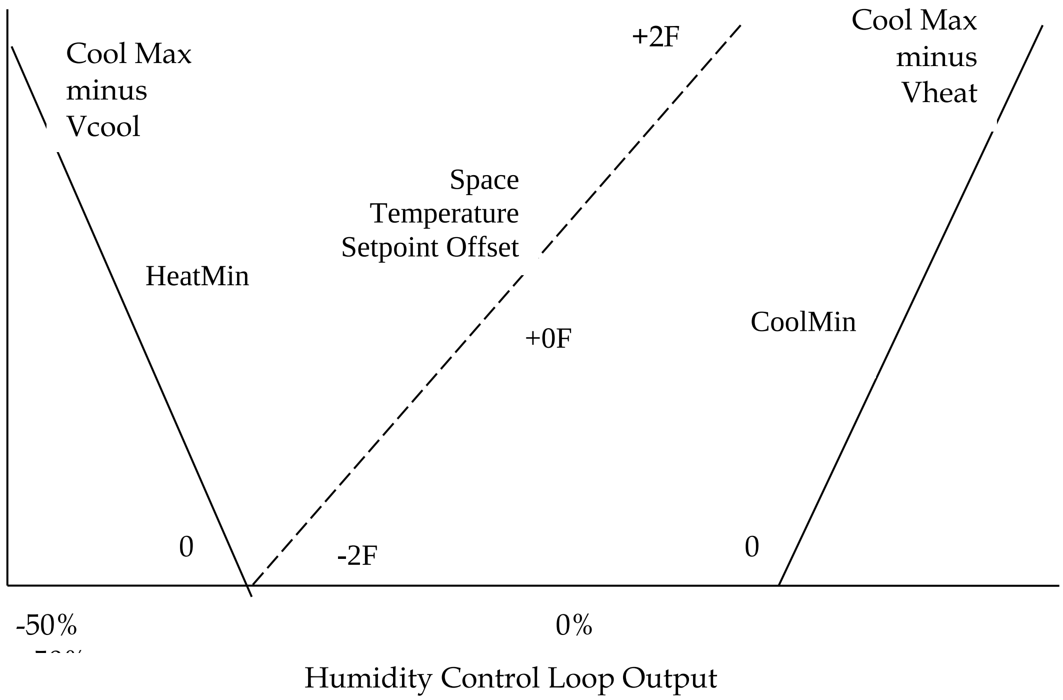


The minimum overall supply (sum of cooling and heating) airflow setpoint shown in Figure 7 is the larger of the following:

- The minimum required for ventilation. This is 0.15 cfm/ft2 reset upwards to as much as 100% of the cooling maximum setpoint based on CO_2 sensors which indicate when and to what extent the space is occupied.
- The minimum required for pressurization and control "inertia," which is determined in the field as that required for stable temperature and humidity control, i.e. the rate that provides sufficient thermal and water vapor "inertia" to slow the impact of a sudden change in people latent load or solar load. It may be high during occupied periods and sufficient only for space pressurization during unoccupied periods. This value will set to 0.15 cfm/ft^2 (the building component of the ventilation rate) initially and raised if it is deemed to be necessary based on trend data during occupied periods.

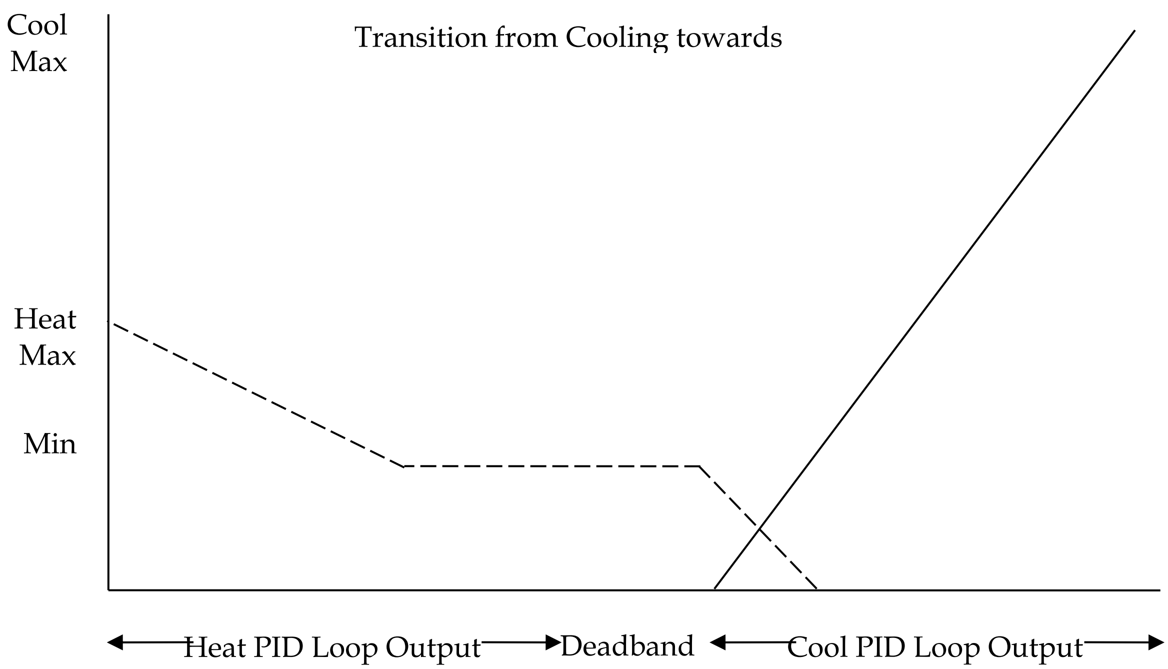
The cooling and heating airflow minimum setpoints are determined as shown below. A direct acting space relative humidity control loop with a setpoint of 50%RH (seasonally adjusted) is mapped to first reset space temperature from 2ºF below the design temperature (72.50ºF) up to 2ºF above the design temperature. If humidity continues to rise, the cooling minimum airflow setpoint is reset from 0 (allowing the other criteria above to dominate) up to a maximum equal to the cooling maximum setpoint less the current heating airflow setpoint. This allows the heating airflow to prevent overcooling of the space. Heating air is relatively neutral with respect to humidity since it comes from all spaces which are supplied by the AHU. If humidity starts to fall, the heating minimum airflow setpoint is reset from 0 up to a maximum equal to the cooling maximum setpoint less the current cooling airflow setpoint. At this point the zone will "request" humidity be added to the hot deck airflow. We expect this to occur rarely, just when infiltration is high during cold weather due to stack effect.

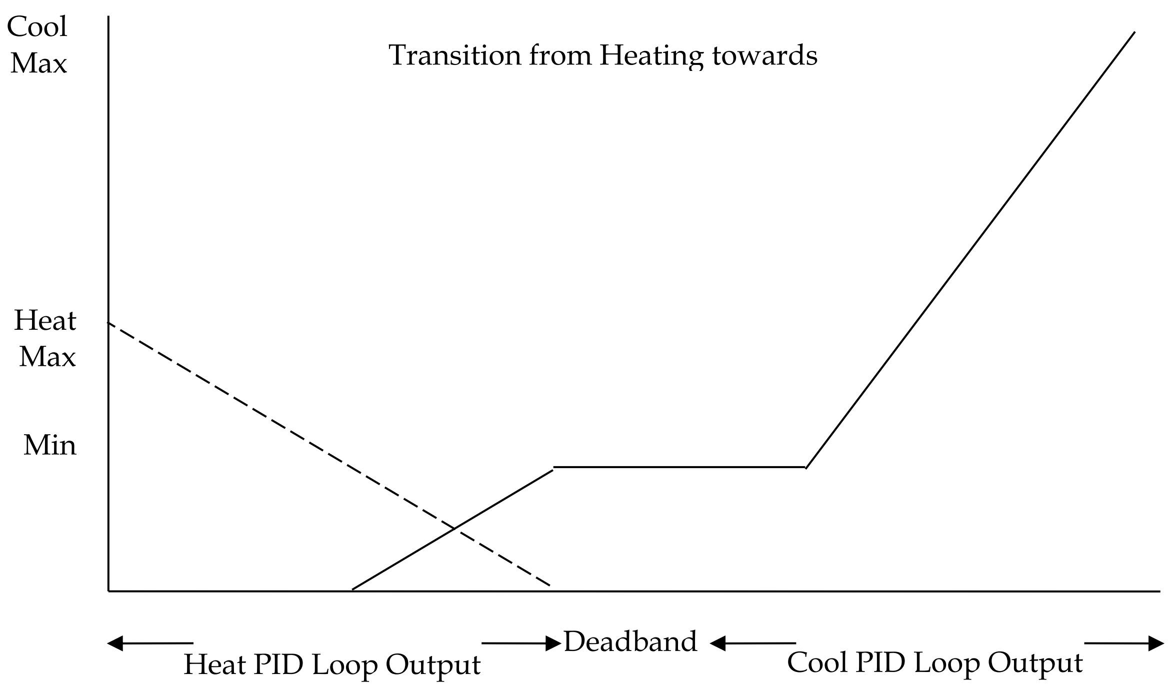
Class A (Gallery) Space Humidity Control



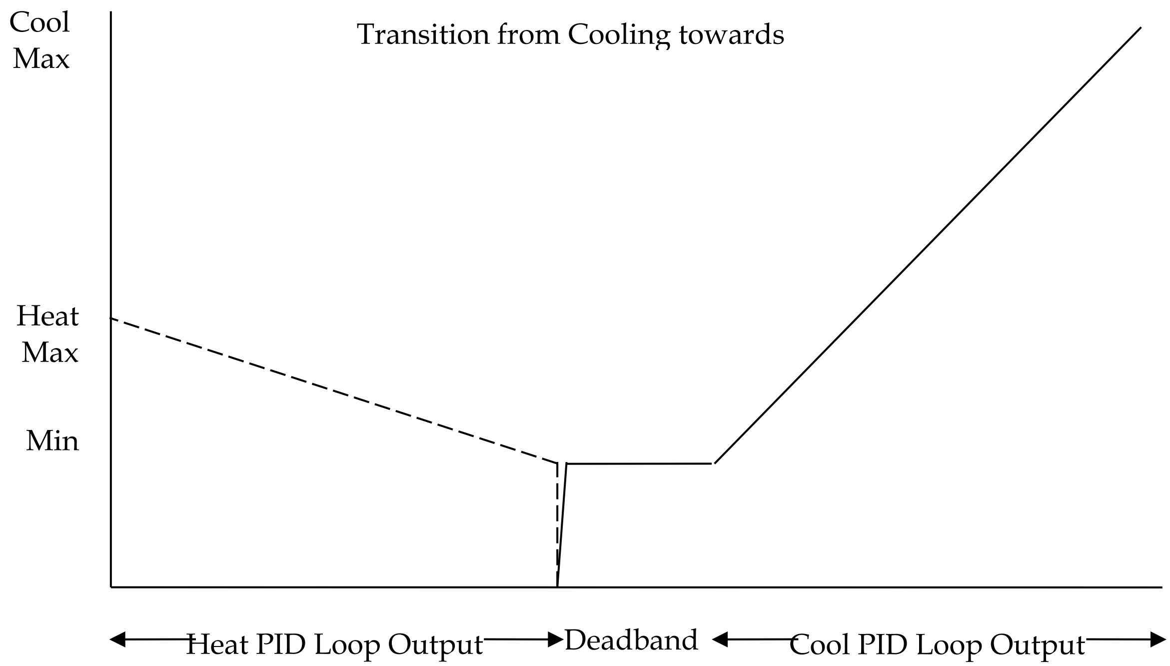
Class B and C temperature and humidity control (non-Gallery or Art Storage spaces) will be maintained by resetting the VAV box cooling and heating airflow rates as shown in the figures below for those spaces with CO_2 sensors where there may be a need to mix hot and cold air together to maintain both CO_2 levels (which may require higher cooling supply air) and simultaneous warm air (to prevent overcooling).

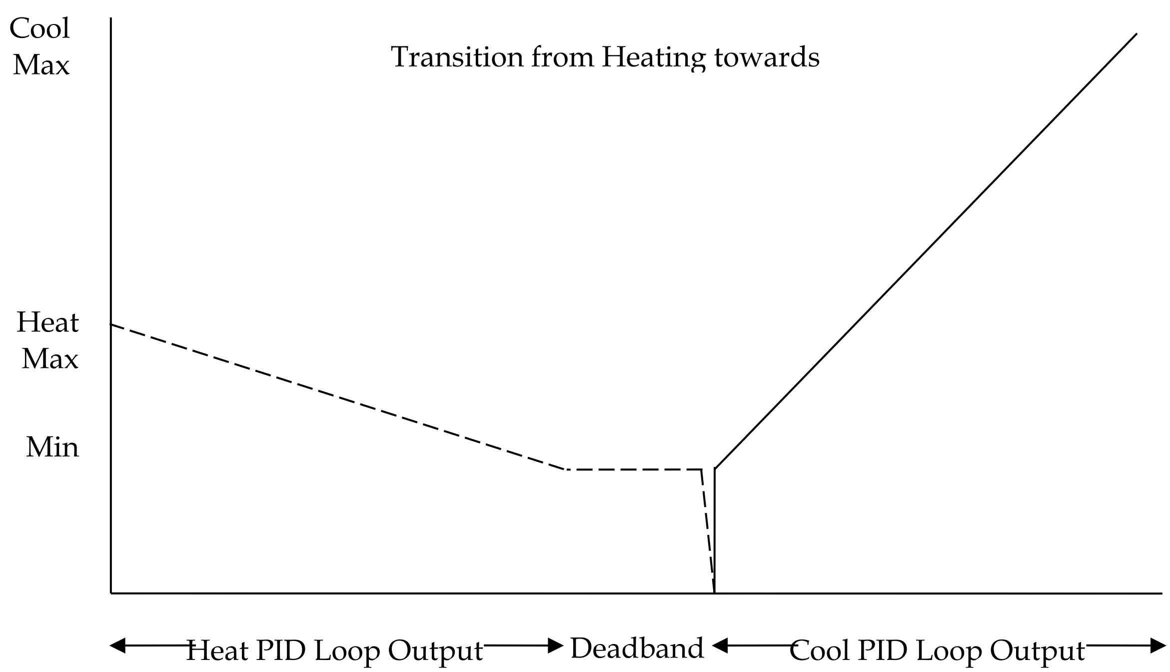
Class B and C Dual-Duct Zone Temperature Control





For spaces without any need for mixing (no CO_2 sensors), the logic will be similar but the minimum will be maintained by one duct or the other one at a time, with the other snapped closed.





Overall minimum airflow setpoints are set to that required for ventilation as described above. Humidity will not be directly controlled in non-Gallery spaces but it naturally will be in the Gallery range since all spaces are served by the same AHUs, except perhaps when a space has a high latent load but low sensible loads.

4.4.1.2 New Air Handling Systems

The new building will be served by new air distribution systems consisting of a penthouse mechanical room with one "cold duct" air handler and one "hot duct" air handler. The air handlers will be located at the top of a main shaft as shown on drawings. A secondary "supply only" shaft near Howard Street will also be used.

Each cooling air handler will consist of:

- Economizer section
- MERV 13 bag filter section. (MERV 8 prefilters will be provided to serve as construction filters to be discarded after startup.) Filters will be standard 24x24x13 sizes for easier maintenance storage.
- 1 row 10 fpi preheat coil
- 8 row 10 fpi cooling coil to maximize CHW ΔT
- Direct evaporative cooler with water treatment system and controls to ensure no microbial growth
- FanWall array with backdraft dampers and multiple variable speed drives

Each heating air handler will consist of:

- MERV 13 pleated filter section. (Bag filters are not used on the heating fans because they will not see the same level of particulate challenged that the cooling AHUs will see; most particles are from outdoor air, not recirculated air. We expect these 4 inch pleated filters to last about a year, similar to the bag filters on cooling AHUs.)
- 2 row 10 fpi heating coil. This coil will result in a 60°F to 70°F ΔT to reduce hot water pump requirements and improve the efficiency of the condensing boilers.
- FanWall array with backdraft dampers and multiple variable speed drives

Cooling and heating air will be supplied down duct risers in both the West and East shafts and will extend onto floors using duct mains.

Expansion area economizer relief fans will be mixed flow type that also will serve as smoke exhaust fans. Fans will have variable speed drives and motorized discharge dampers which will serve as the first stage of relief.

All supply and relief fans will be on emergency power for smoke exhaust/pressurization and also to provide partial conditioning during a power outage.

4.4.1.3 Existing Air Distribution System Modifications

The existing Botta Building air handling systems will be fully replaced with a new system including all new coils, dampers, fans, etc. to match the design of the new AHU as described above. Because of space constraints, the new system will be "built-up" from basic components rather than using a packaged air handler. The new design will be much more energy efficient and provide much lower maintenance costs than the existing system. Maintenance access will also be dramatically improved.

New relief fans will also be installed for economizer relief, similar to the expansion AHU design. We evaluated the approach of using the existing Botta atrium smoke exhaust fans as relief fans in the new configuration – they are located in the right location and configuration and are adequately sized. We decided that they are not acceptable to use as relief fans because they are too noisy for daily operation given their location right in the atrium with no attenuation. In smoke mode noise does not matter, so quiet operation was not a concern when these fans were originally selected.

Our calculations indicated that the Botta systems are oversized for the existing loads, confirmed by the fact that only one of the two vane-axial pairs were ever operated at a time. This excess capacity allows these systems to be extended into Levels B through 5 of the expansion areas, reducing the size of the expansion AHU on the roof.

4.4.1.4 Zone Air Distribution

Supply air distribution will be via overhead ceiling-mounted or duct-mounted diffusers and grilles.

Return air distribution will be at the ceiling level via a plenum return using little if any ductwork. Transfer ducts and acoustic boots will be used to allow return air to migrate properly and provide acoustic separation between spaces.

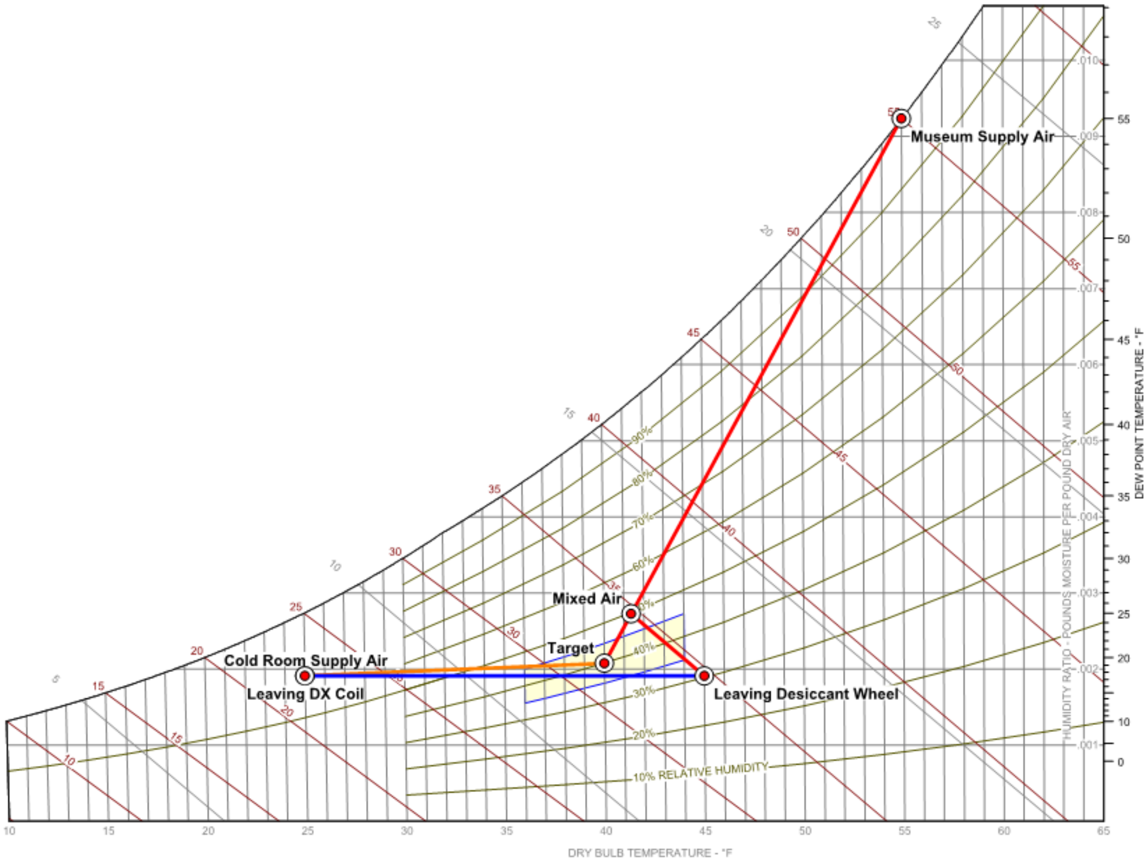
All ductwork that passes across the building seismic joint near gridline 7 will be fitted with flexible connections to allow for the expected building movement.

4.4.2 Cold Room / Cool Room System (Class AA)

Because the AA criteria spaces require low relative humidity (40% to 45% RH), supply air must have a dew point (DP) temperature of 37°F. To get to this DP with a chilled water (CHW) coil would require a CHW temperature of at least 32°F, which would require a glycol mix in the CHW lines. We wanted to avoid the use of glycol since it is both expensive and decreases the energy efficiency (heat capacity and heat transfer) of the equipment it passes through. Further, using a CHW coil for dehumidification would require a deep coil and significant reheat.

Instead of a CHW coil, we designed the system to employ a desiccant dehumidification unit to achieve the required supply air dew point temperature. Desiccant dehumidification is an adiabatic process that pulls the moisture out of the air and at the same time raises its drybulb temperature.

The psychrometric chart below shows the Class AA system performance under the design summer dehumidification scenario.

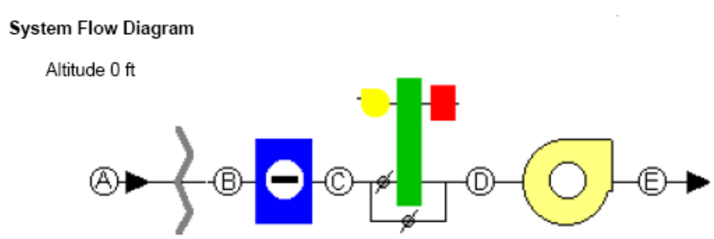


"AA" System Process (Psychrometric Chart)
Design Dehumidification Conditions

The museum (Class A) supply air is mixed with return air from the space and run through the desiccant dehumidification wheel and dried/heated. The chart shows this as an adiabatic process where the moisture level goes down and the DB temperature goes up. Air leaving the desiccant wheel is at the point labeled as such.

Air leaving the wheel is then cooled with a DX cooling coil to the "Cold Room Supply Air" point where it is then introduced to the room for conditioning.

The diagram below shows a schematic of the dehumidification unit.



The unit dehumidifies air by driving it through the desiccant wheel. The amount of dehumidification varies by how much air goes through the wheel and how much bypasses around the wheel with the face and bypass damper arrangement.

4.5 Ventilation

Ventilation air will be delivered to the building through central cooling air-handling systems located on the roof. Outdoor air is not supplied by the heating air handlers. For zones in heating mode, ventilation is provided indirectly from zones that are in cooling mode, such as interior zones and process areas (IDF and elevator rooms) served by VAV boxes. Calculations indicate that these loads will cause the cooling AHUs to supply more than the absolute minimum outdoor air rate.

Minimum outdoor air will be controlled by airflow measuring stations (AFMSs) in the minimum outdoor air intakes. AFMS will be thermal anemometer type so that low velocities can be measured. Minimum outdoor air will be reset from zero in unoccupied areas to the minimum building component rate in low density occupied areas up to the design fully occupied rate based in zones with CO_2 sensors so the overall outdoor air rate can vary more than 5 to 1 depending on conditions.

4.6 Exhaust Systems

4.6.1 General Exhaust

Exhaust systems are provided for toilet rooms and janitor rooms using a fully ducted exhaust system. Makeup air will be through a combination of transfer air through door undercuts, ceiling transfer grilles, and condition supply air as required to meet loads.

4.6.2 Conservation Area(s) Exhaust

Dedicated Conservation exhaust will be provided at the roof level drawing air from a ducted exhaust system.

Conservation exhaust will consist of local exhaust snorkels and a spray booth. Fans will be variable speed and sized for N+1 redundancy.

The conservation lab HVAC systems will be designed to meet the program requirements established by the conservation area architect and outlined in the Program Document.

4.7 IT Rooms and Other 24x7 Areas and Systems

IT rooms and other spaces with 24x7 loads will be cooled by water-cooled air conditioning units or heat pumps and, for larger rooms, also by a cooling-only VAV box as required under the 2014 energy code. The AHU is not sized for the IT room load so the VAV box will provide cooling first but limit capacity when the VAV system is no longer able to handle the load, as indicated by static pressure setpoint being at maximum. The water-cooled AC unit then takes over.

Electrical equipment rooms and most elevator machine rooms will be cooled using transfer plenum air to maintain maximum temperatures allowed by the manufacturer.

Kitchen refrigeration and cold-room equipment will be water-cooled and served by the closed circuit condenser water system.

4.8 Building Pressurization

All spaces will be maintained at a slight positive pressure relative to the outdoors to mitigate infiltration of unconditioned and unfiltered air. Vapor barriers in the building envelope prevent moisture from condensing in the walls in cold weather.

4.9 Life Safety

The final expanded building will be provided with a single integrated smoke-control system and stairwell pressurization system as required for high-rise construction. This single final system will incorporate existing building systems and fans as well as new building systems and fans. The complete system will comply with CBC requirements and will be designed based on the requirements established by the life-safety consultant in the Smoke Control Rational Analysis report.

4.9.1 Atrium Smoke Exhaust

Smoke exhaust will be accomplished using new building relief fans as well as the existing building atrium smoke exhaust fans. All fire/smoke dampers and building fans that are part of the life-safety system will be controlled an integrated fire management system whenever the building goes into smoke-control mode. The normal building DDC controls will not be employed in smoke-control mode.

The atrium will be split into two separate smoke zones: 1) Botta + Minna end, and 2) Howard end. Smoke in zone 1 is contained by mechanical supply (existing AHUs) and mechanical exhaust (existing smoke exhaust fans). Smoke in zone 2 is contained by mechanical supply (stairwell and elevator pressurization fans only) and mechanical exhaust (new relief fans).

Floors 8,9,10 will do smoke control by exhaust only to maintain floor pressurization.

See Smoke Control Rational Analysis report for required airflow rates.

4.9.2 Floor Depressurization

Each floor will be capable of being exhausted to maintain the floor at a negative pressure relative to other floors per code. The building economizer relief fans using drywall return air shafts will be used for this purpose. (Note that this requires that the Smoke Control Rational Analysis report exclude the return air shaft from leakage tests.)

4.9.3 Stairwell Pressurization

Each stair will be supplied by pressurization fans located at the bottom or top of the stairs drawing from louvers typically located over the stair exit doors. Air is ducted to vertical shafts within the stair footprint. These fans indirectly pressurize stair vestibules by controlling the leakage rate from the stair to the vestibule and from the vestibule to the tenant space using adjustable door sweeps (threshold seals). Pressurization will be sized by the Life Safety Consultant to maintain positive pressure in the stair and vestibule in accordance with code.

See Smoke Control Rational Analysis report for required airflow rates.

4.9.4 Elevator Shaft Pressurization

Each elevator shaft will be supplied by pressurization fans located at the top of the shaft drawing in air from the outdoors.

See Smoke Control Rational Analysis report for required airflow rates.

4.10 Redundancy

Except as specifically listed above, no redundant equipment is provided. To mitigate exposure to equipment failure, all air handlers, the central heating plant, and the central cooling plant will have a minimum of two pieces of each type of equipment. Air handlers will have multiple fans in parallel and thus have significantly reduced exposure to equipment failure. Cooling towers include three cells, each capable of handling one of the existing chillers so that both existing chillers can operate at design capacity even if one tower cell is down.

Distribution systems and control systems will have no redundancy.

Control sequences will shed non-critical Class B, C, and D spaces by raising cooling setpoints and lowering heating setpoints whenever:

- A piece of equipment (e.g. chiller) fails and the weather is warm
- PG&E power is lost and the building is running on generator.

The main air handlers and one each component of the chilled water plant are served by the generator. With the load shed from noncritical spaces, the AHUs and cooling systems will have sufficient capacity to maintain temperature and humidity in the critical Class A areas.

5. HVAC System Construction Approach

5.1 Purpose of this Section

The goal of this section of the Basis of Design is to describe how the HVAC system construction approach meets the project needs as described above.

5.2 Purging During Construction

A post-construction fresh-air purge of the building is required to flush construction pollutants out of the building prior to occupancy.

5.3 Commissioning

A formal commissioning process will be applied to this project. See the detailed commissioning plan document for a full description of the commissioning activities for this project. To summarize, the commissioning approach for this project includes:

- Peer Reviews of Systems Design
- Submittal Reviews
- Controls Review
- Functional Testing
- Trend Reviews

The owner has engaged a 3rd Party Commissioning Agent to perform a series of Commissioning Tests on the project to ensure that the final building installation meets the design intent requirements. The contractor will be expected to cooperate fully with this testing and to remedy any issues raised by this commissioning process.

6. HVAC System Equipment

6.1 Purpose of this Section

The goal of this section of the Basis of Design is to explain what types of equipment and systems were chosen for this project and why. The idea is to explain the logic and thinking behind equipment selections.

6.2 Chillers

A third chiller similar to the two existing chillers was originally chosen for this project but budget constraints required that the chiller be sized to just meet the added load. Basis of design chiller is a McQuay scroll compressor chiller. The unit was selected for the maximum ΔT available to match the existing chillers and new coils. The ΔT on the chilled water side is limited so the minimum flow bypass will ensure that return water temperatures will not be excessively warm.

Acceptable manufacturers:

- McQuay
- Carrier
- Trane
- York
- equal

6.3 Cooling Towers

Propeller cross-flow cooling towers were selected for this project because propeller fans use about half the energy of centrifugal fans and cross-flow towers are the easiest to maintain. Propeller fans are excellent at moving large quantities of air at low static pressures, which is the duty we have here. Basis of design cooling towers are BAC model 3000 units. Initial designs included gear drives and external motors, but value engineering resulted in the use of belt drives with motors in the airstream.

Acceptable manufacturers:

- BAC
- Marley
- equal

6.4 Pumps

In most cases, existing vertical inline flex-coupled pumps are reused. New small condenser water pumps will be close coupled inline pumps. Armstrong is the basis of design to match existing.

Acceptable manufacturers:

- Armstrong
- B&G

- Paco
- equal

6.5 Desiccant Unit

The desiccant unit chosen for this project is a packaged unit with packaged controls manufactured by Munters. Munters was chosen as the basis of design based on a good track record with similar equipment in the Bancroft Library and the North Regional Library Facility also operated by the University of California.

Acceptable manufacturers:

- Munters
- equal

6.6 Air Handling Units

HuntAir "Fan Wall" units were selected as the basis of design due to their compact size and excellent acoustic performance. On the Botta built-up units, only the fans themselves will be HuntAir – the coils may be provided from any acceptable manufacturer and plenum walls are all field built.

Acceptable manufacturers:

- HuntAir
- Energy Labs
- equal

6.7 Controls

The existing Staefa system is obsolete and will be completely replaced. All HVAC systems (new and existing) will be controlled by a new native BACnet energy management & control system (EMCS) with distributed intelligent controllers and new front-end server.

All HVAC systems (including zones) will be controlled by a direct digital control (DDC) system with distributed intelligent controllers and front-end computer with color graphics.

VAV boxes will be logically grouped in software to functional areas they serve (Zone Groups), each operating on a different time schedule. This will allow areas to be shut off or set-back when not occupied, saving energy since fan systems will run 24/7. Zone Groups are assigned in VAC box schedules.

Equipment provided under Division 26 will be connected to the EMCS via network interfaces to allow the system to monitor and control all systems from a single east. This includes lighting controls, UPS, and power meters.

Some of the newer existing HVAC systems have Alerton controls, but not enough to encourage limiting the new system to Alerton. Automated Logic is the preferred system and basis of design due to its high level of performance and reliability and because there are three ALC dealers serving the Bay Area.

Acceptable manufacturers:

- Automated Logic
- Alerton